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Centre of Excellence in Farm Business Management

The Usefulness and Efficacy of Linear Programming Models as Farm Management Tools

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Executive Summary

This study evaluating the usefulness and efficacy of linear programming (LP) models, and the Grazing Systems Ltd (GSL) model in particular, was undertaken for DairyNZ by the Centre of Excellence in Farm Business Management. The GSL model was selected because it is the only LP model available for use in the farm business environment in New Zealand. Two approaches were used to evaluate the usefulness and efficacy of LP models and the GSL model as farm management tools. The first approach involved case studies with two farm consultants experienced in the use of farm management models who worked with dairy farmer clients using the GSL model. The case studies resulted in an evaluation of both LP and the GSL model. The second approach was an expert evaluation of the GSL model conducted by members of a research panel with LP experience who evaluated the GSL model against a set of LP modelling criteria they developed.

The two consultants used the GSL model differently. One consultant‟s client was familiar with the use of models and the consultant discussed results with his client as they were being generated. The other consultants‟ clients were familiar with output from other models but preferred to have the consultant do the modelling and present them with the results. This consultant did the initial modelling in the GSL model, then subsequently in a model his clients were familiar with. Each of the three clients was presented with results indicating that a change in practice would result in improved farm profitability. Two of the three clients decided to implement the changes. The other client required further analysis regarding the changes indicated by the model.

Despite the different approaches, both the consultants and their three clients said they found the information obtained from running the model interesting and useful in assisting them to make decisions about their farm systems. The study concluded that LP can provide information to assist with improving farming systems, but the LP model has to be carefully constructed and interpreted so that model users will have confidence in the answers it provides. Users who are familiar with the concepts of marginal analysis will find that LP can provide valuable information to help with improving farm systems.

Both consultants considered the GSL model relatively easy to work with and noted that it generated results quickly. The consultants found it helpful to have worked directly with the GSL model developer in more than one briefing session to gain model experience. The expert panel also found the GSL model to be relatively easy to work with and it measured well against many of the criteria. However, consultants and panel members made a number of suggestions that would help to improve the "commerciality" of the model, such as an improved manual and formal training, better input and output functionality, and better model availability. Potential users expect to be able to easily find information on the model from a range of sources, yet little information is available. If the GSL model is to be more widely used and accepted as another tool in the farm management kitbag, it would be helpful to improve its accessibility, data input and, in particular, data output.

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1.0 Introduction

DairyNZ is interested in tools that can be used by farm management consultants and their farmer clients to assist with decision making. The Centre of Excellence in Farm Business Management has conducted on-going work in the Farm Tools domain to contribute to this objective. As part of that work, this study assessed the value of Linear Programming (LP) to farm management consultants and their dairy farmer clients in identifying feasible and profitable changes to their farming systems.

LP models have been available to assist in designing improved farming systems since the late 1950s (Malcolm, 1990). Yet despite their perceived potential, their use in agriculture has been primarily limited to the development of least cost feed rations for intensive pig, poultry and feedlot farming systems. Use within the New Zealand pastoral farming sector has been limited and the technique is rarely used by farm management consultants.

This study assessed the usefulness of the Grazing Systems Ltd (GSL) model to consultants and their clients, and evaluated its robustness and efficacy in identifying optimal and feasible dairy farming systems. The GSL model was selected for this evaluation because it is the only known LP model currently in use that has been developed for farm consultancy in New Zealand. GSL model use in New Zealand dairy systems has previously been reported in Anderson and Ridler (2010a, 2010b) and Ridler, Anderson and Fraser (2010).

The following research questions were identified.

1. Can linear programming models help farm management consultants work with their dairy farmer clients to develop improved pastoral-based dairy farm systems?
2. How effective and robust is the GSL linear programme model as an aid to dairy farm management decision making?

Chapter 2 provides background information on modelling in farm management, theoretical aspects of LP and the GSL model. The methods used to examine the research questions are described in Chapter 3. This is followed by the results, with the findings from the expert evaluation of the model presented in Chapter 4 and the results of the three case studies in Chapter 5. These results lead on to the Discussion in Chapter 6, followed by the Conclusions in Chapter 7.

2.0 Background

2.1 Modelling in Farm Management

Since farm management has been recognised as a discipline, farmers and their management advisers and consultants have used models to represent the reality of farmers" businesses. Cash flow and cash forecast budgets, partial budgets, capital investment budgets and feed budgets were early farm management models, which were initially carried out using pencil and paper, followed by simple calculators then early forms of computers. Farm management models were able to be readily adapted to computers, especially with the advent of spreadsheets. More sophisticated financial and biophysical computer models were later, quite quickly, developed for use in farm management decision making and research, mainly in the form of simulation models.

Malcolm (1990) noted in his review of academic literature about farm management in Australia that:

> The traditional, relatively simple, farm management budgets have stood up well to tests of time because they enable the full dimensions of the problem to be brought into consideration. Further, the computer spreadsheet has enhanced the analytical power and problem solving relevance of the traditional farm management budgets. (p. 52)

There is now comprehensive literature on the use of models in farm management research, consulting and practice (see for example McCown, 2002). In the New Zealand dairy industry, the most widely used commercial simulation models are UDDER (described in Dooley, 2012, Appendix 4) and Farmax Dairy (described in Dooley, 2012, Appendix 3). These simulation models were primarily designed to generate a range of scenarios enabling practitioners to evaluate a range of alternative systems and select those that best fitted their objectives. This is in contrast to the role of LP models which find the system with the optimum use of resources, usually with the objective of maximising financial returns or minimising costs. It should be noted that the UDDER model has optimisation capabilities as well as simulation capabilities.

Prior to the research in this study being undertaken, a brief search of recent literature was undertaken to identify any studies evaluating models for use by consultants and their clients, particularly where LP and simulation models were being compared, and to help provide criteria against which models might be evaluated. While no such comparisons were evident, some papers of relevance to this study were found

Nuthall (2011) provided a brief overview of analytical methods for farming systems. In this, he observes that.

> LP has become an important tool for researchers, but not so much for consultants and farmers, particularly as considerable experience is required to develop realistic models and adequately analyse the outputs. (p. 3)

Malcolm (2004, p47), reviewing the Australian context, argued that “farm models can only ever be partial representations of reality”, and that “it is incumbent on those who carry out farm management analysis to get it right”. Malcolm (2004) saw the modelling analysis as the thought processes surrounding the use of modelling techniques (which were often fairly basic) rather than the use of the actual models themselves.

In the Australasian context, these two prominent researchers, Nuthall (2011) and Malcolm (2004), were not convinced of the value of models, and in particular LP models, as aids to decision-making and suggested that other avenues might be better pursued. However, the current environment is such that consultants and their technology-savvy clients are becoming more accustomed to using models. Hence, one purpose of this research was to see if LP models were likely to add to the quality of the decisions being made. When models are used, both researchers noted that these models need to be carefully constructed, use reliable data, and the results need careful interpretation if the models are to be useful decision aids.

An entire issue of the Agricultural Systems Journal was devoted to Decision Support Systems (DSS) in 2002 and a prolific writer in this area, Bob McCown (McCown, 2002), identified the “persistent „problem of implementation“”, which amounted to a reluctance to engage with DSS by family farms in particular. He concluded that:

> Users must undergo an iterative learning and practice change process. The researchers must be prepared to be involved in, lend support to, and learn from this process – learn what farmers are learning and learn what this means for conduct of their own future activity. This is the essence of action research. (p. 216)

Janssen and van Ittersum (2007) reviewed 42 different bio-economic farm models, which were essentially defined as mathematical programming models that are variations on LP. They defined and distinguished between approaches that were “empirical versus mechanistic” models on the one hand, and “normative versus positive” on the other, with a focus on mechanistic models which were often based on LP and its variants (Janssen & van Ittersum, 2007). They strongly proposed the development of:

> …a consistent and widely accepted model evaluation procedure, comprising steps of checking the correspondence with observable values, calibration and validation. (p. 624)

These latter two papers serve to underline the fact that, while many academic papers have been written about the use of models in agriculture, evaluation criteria and the means to implementation were considered lacking. To address this, McCown (2002) called for researchers[4] to engage directly with model users in an action research framework.

2.2 Linear Programming Models in Farm Management

LP is a mathematical (algebraic) technique whereby relationships between resources and outputs in a system are described by a set of algebraic (linear) equations. Because resources are limited, output will be constrained. Defining constraints on resources is a crucial part of building an LP model. The resource and output equations are linked to one another by another equation called an "objective function" which describes the desired outcome in mathematical terms. The objective function usually represents the cost and returns of the system, and the objective described by the objective function is usually to "maximise profit". A matrix of equations is set up and, by the mathematical process of matrix inversion, moves progressively closer to the optimum solution, which in economic terms is usually maximum profit.

The information resulting from this mathematical process includes, not only the level of resource use required to meet the objective function, but also which of the resources is constraining the system from increasing profit further (i.e. limiting resources) and by how much that profit would increase if another unit of that limiting resource became available. In mathematical terms, this value is called the marginal value product (MVP) and, in economic terms, the opportunity cost or shadow price. This information can be extremely useful for evaluating and designing farming systems. The relationships between resource use and opportunity cost are explained in more detail by Makeham and Malcolm (1993) and by the GSL model developer, Barrie Ridler (Ridler, Anderson & Fraser, 2010).

Describing a grazing system as a set of mathematical equations is not an easy task, and the diagrammatic representation of a grazed livestock production system (Figure 1) prepared by the GSL model developers (Anderson & Ridler, 2010*a)* does not fully reflect the model"s complexity. The quantitative information about the relationships between the model variables is typically held by many different people. Farmers and consultants usually rely on agronomists, soil scientists and animal nutritionists to help explain the complex relationships between the essential parts of the system. However, scientists prefer to describe the relationships in more complex terms than the linear equations required by an LP model, perhaps explaining in part why simulation models are more readily accepted than LP models. And, while bank managers and accountants can search for financial information in their farm records and annual accounts, these records are often not in the format required for farm management purposes and these people are often not familiar with the form of farm information that is used in generating an objective function.

[4] In this context McCown talks about researchers as those who have developed underutilised models, or in the terms of this report, the "model developers".

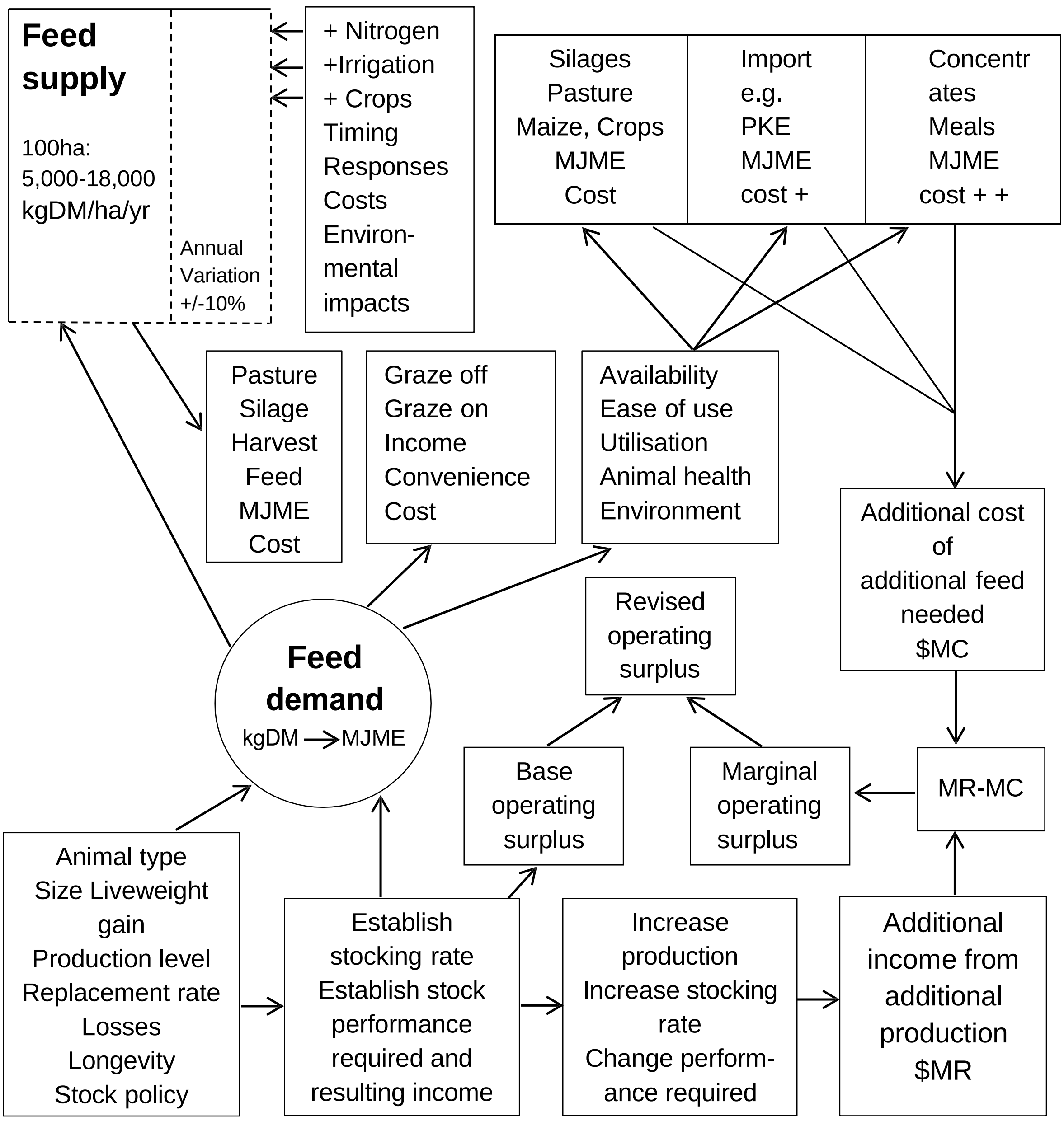

Figure 1: A model representing the relationship between feed supply, feed demand and production economics in a grazed livestock production system. MJME = Megajoules of metabilisable energy; MC = Marginal cost; MR = Marginal revenue; DM = Dry matter; PKE = Palm kernal expellar. Figure reproduced from Anderson & Ridler, 2010a, p. 25.

One of the most difficult relationships to describe is grazing management because of the interactions within the system (Holmes et al., 2002). If pasture is grazed to a particular level in a given week, this will influence the rate at which it grows over the ensuing weeks; if grazed to a different level, a different subsequent growth rate occurs. Therefore, a useful model must be able to take account of these interactions through a reiterative process to account for the range of permutations and combinations that can result from modelling a particular grazing activity over a range of time periods (Holmes et al., 2002). Many iterations of the matrix inversion process are necessary and it is only the increases in computer capacity in recent times that have enabled this to be done in a manageable timeframe.

A similar complexity arises with livestock feeding (Holmes et al., 2002). The relationships linking feed intake with levels of milk production and cow bodyweight and condition, vary with the physiological status of the cow through the milking season. Many iterations are needed to model the trade-offs between production and cow condition.

These complexities and the difficulties in modelling these relationships mean that consultants and their clients have to be confident in the efficacy of such models, and need to be convinced that the model represents reality for the farm being modelled.

2.3 The Grazing Systems Ltd (GSL) LP Model

During the 1980s and 1990s, academics at Massey University realized the value of data relating to farm physical performance and sought ways to use those data as a means to improved farm performance on university and other commercial farms. The precursor to the current GSL model was developed at that time, using these data.

The current GSL model, which was constructed by Jade software, uses sophisticated programming techniques and has enhanced computational speed. The model is a multi-period (seasonal) model that assumes that coefficients, costs and constraints are known with certainty. Pasture supply constraints are specified as pasture covers through time. This GSL model can be accessed on-line from desk-top or lap top computers to aid dairy farm management decision making. The model is promoted by its primary developer, Barrie Ridler from GSL. Barrie Ridler (personal communication, 2013) believes that, through its optimising routine and MVPs, LP model output is able to help users achieve an understanding of their system that is not available from using other models.

Although this GSL model has been promulgated over recent years, general awareness of the model in the industry remains limited and the model is only accessible to the farm consulting profession within New Zealand by contacting the developers directly. However, this GSL model is the only farm management LP model in New Zealand designed for business use.

3.0 Method

Case study and expert evaluation approaches were used to evaluate the efficacy and robustness of LP models for the design of improved farming systems and, in particular, the use of the GSL model for this purpose. The research questions required that the LP model be assessed against a range of criteria. The literature discussed in the background chapter provided some evaluation criteria, reflecting lessons that have been learned in the past about LP and other models. Criteria were also identified during the case studies, and pre-defined by the researchers in the expert evaluation group. There were similarities in the questions being considered in each of the approaches, so that the criteria identified from these different sources overlapped and complemented each other. The approaches used for the expert evaluation by a research panel and the case studies are described further in the sections below.

3.1 Briefing Sessions and Model Access

Consultants and members of the research team were briefed by the developer on the conceptual aspects of LP and the specific means of setting up and running the GSL model. Working examples were used to demonstrate data input, and obtaining and interpreting output from the model. Members of the evaluation team participated in the first briefing session at Massey University, together with some other interested people. Three other briefing sessions were held in different locations for the two consultants (one-to-one sessions) and one of the evaluation team members, as either the timing or the geographical location of the first session did not suit those people.

Each consultant and evaluation team member was given on-line access to the GSL model, along with model instructions and examples of model output reports as an aid to understanding. As the project progressed, the model developer remained available for members of the group (consultants and researchers) to consult to clarify and discuss model operation. Consultants in particular availed themselves of this opportunity. The developer also provided them with some assistance in setting up model scenarios.

3.2 Expert Evaluation by a Research Panel

The model was evaluated by a research panel with respect to its efficacy and robustness. Researchers with previous experience in the use of LP and other farm management analysis models participated in the evaluation. These researchers had previously been involved in research projects where LP and simulation models were developed and used in farm management and other systems applications and analyses. Some had also been involved in farm management consultancy, and/or in teaching the applied and theoretical aspects of LP to undergraduate and graduate students.

This panel met twice, the first time in a conference call in the early stages of the project and the second time, face-to-face to discuss the findings. They also communicated with each other by phone and email throughout the project. The GSL model was reported on by three members of the group with results from two members reported in the GSL model evaluation by the research panel (Chapter 4). While the expert evaluation was undertaken by a panel independently of the case studies, one of the panel also observed the case studies and her observations on the model and its use are reported in the GSL model case study results (Chapter 5). The evaluation of the efficacy and robustness of the model was also informed by the reports from the two consultants.

Based on their experience with models, including LP models, the research group devised a pre-defined set of criteria, with associated questions, against which they would evaluate the model. These criteria are shown below.

- Clarity of instructions: Is it easy to learn to use the model or does it require several training sessions? Is the manual helpful and easy to follow?

- Simplicity of use: Is the model intuitive to use? Is data entry quick and simple? Are parameters easy to alter? Can multiple solutions be compared to each other? Are results well-presented so they are easy to understand? Is the model easy to navigate around? Can the base system be set up quite quickly?

- User level: What level of user is the programme most suitable for (e.g. farmer, technician, consultant)? What elements of the model require user expertise? What level of guidance does the model provide the user with? For example, the Farmax model will tell a user if a solution is infeasible based on pasture cover levels.

- Accuracy: How accurate do the results appear to be (biophysical and financial)? How do the results the GSL model came up with compare to Farmax DairyPro, bearing in mind Farmax is a simulation model and does not optimise?

- Understandability: How useful/easy to understand are the outputs? Does the model provide shadow prices? Is post-tax cash surplus or a gross margin modelled? Is this with or without capital costs?

- Scenario analysis: What scenarios can be easily modelled? What scenarios are difficult to model? e.g. integers, capital items.

- Risk: Can the model incorporate risk?

3.3 Case Studies with Consultants and their Clients

The GSL model was evaluated by two experienced consultants and their farmer clients who used the model to help resolve real world issues on the clients" farms. The two[5] consultants were selected on the basis of their interest in participating in the research and their experience in working with other computer models. Both consultants used the UDDER simulation model as part of their regular consulting process and one consultant also used Farmax Dairy. Thus, these consultants were able to make comparisons between LP and simulation models, and these two models in particular.

The consultants selected the consultancy approach that they would use with the GSL model, taking into consideration what they thought would garner the most useful information from their perspective and the nature of their relationship with their client. Each consultant selected a farmer client or clients who had a farm systems issue that could be addressed by the GSL model.
Consultant A undertook the evaluation with a single client, whereas Consultant B evaluated the model with two clients.

As part of the evaluation, the consultants were asked to compare the GSL model to other models (which were simulation models) currently used for farm systems design and evaluation. The consultants were also asked to model the solution(s) identified by the GSL LP model using another farm system tool, such as the Farmax Dairy or UDDER simulation models, to compare model outputs as an aid to model validation. Important criteria for model evaluation were also identified during the consultancy process.

The consultants and their clients were interviewed both, prior to and, following the consultations. These interviews were carried out by phone, digitally recorded and transcribed verbatim for analysis. To capture the consultants" and their farmer clients" initial views, a semi-structured interview was held with each consultant and each client prior to their GSL model briefing and prior to the consultant"s visit. They were asked about their knowledge and experience with models, and their expectations and views on the LP model, the modelling process and what they believed would be a good outcome. Clients were asked about the service their consultant provided and consultants about the service they provided. The open-ended questions (Appendix I) asked during these interviews were similar for both the consultants and the three farmer clients. After the visits, the consultants and clients were interviewed again and asked further open-ended questions about their experiences with the model (Appendix I).

The LP model was evaluated by the two consultants during one or two consultancy visits with each of their farmer clients in which the GSL model and outputs from the GSL model runs were discussed. The consultancy visit(s) where the consultant interacted directly with his client using the GSL LP model was observed by the researcher, and the voice commentary was digitally recorded and transcribed for analysis. The same researcher interacted with the consultants throughout the case studies (in both interviews and observation of the consultation process) and therefore had a broad overview of the whole process and the context for each case study.

[5] A third consultant was also involved in the early stages of the project but was unable to complete the process for personal reasons. Some of the insights gained are attributable to his contribution.

Each consultant provided a written report which included a summary of the results they generated and their experiences with, and opinions of, the GSL model. The consultants" case reports written for each client were also provided.

The data provided by the interviews, consultancy visit observation and reports were analysed using qualitative data techniques. Each case study was analysed according to the processes and interactions that occurred. Of particular interest was the nature of the information generated and how the information was used, and how useful this was in the consultancy process. The approaches and processes of the consultants to their role in the study and the results they achieved were summarised and tabulated for comparative purposes.

4.0 GSL Model Evaluation by the Research Panel

An expert evaluation of the model was undertaken by members of the research panel. One member of the panel (Guy Trafford) provided a comprehensive evaluation of the GSL model as a farm decision support programme against the questions developed for this purpose. This researcher is an academic who is familiar with the construction and use of linear programmes for farm management and research. After spending some time with the programme, the researcher felt able to make qualified comments against most of the criteria. His observations are provided below in normal font. Observations on similar points are provided by another member of the panel are shown in italics. Information relating to model access and commercial availability, which were not included in the initial set of criteria, are also commented on.

4.1 Instructions

The instructions provided for the programme need further development, both in the detail provided and in the format. Someone who is unfamiliar with LP, or has not had the benefit of being shown how to operate the programme, is likely to experience difficulty in engaging with it. The instructions suffer from the developer being very familiar with the GSL model and perhaps not appreciating the difficulty a lay person would have interpreting them. Including graphics of the layout and a contents page would assist, as would the inclusion of a mock farm and problem which the learning practitioner can work through. This would allow the person learning to check their result to confirm they are interpreting instructions correctly.

The manual provided was not particularly well laid out or intuitive. The informal format of the instructions provided was such that these may have been written for the benefit of those involved in this project. For commercial purposes, a more professional manual / set of instructions needs to be developed, including screenshots to demonstrate model use, and background information on the model, linear programming and how to interpret results. This would assist users who are more accustomed to working with spreadsheet models, or simulation models such as UDDER or Farmax. It is uncertain whether a manual for the GSL model exists: there may be very few users of the model other than the developer who also uses the model on behalf of clients.

The model installation and set-up instructions were informally presented and were provided by email. For commercial purposes, a more formal set of instructions might be expected. These could possibly be included in the manual, which would also ensure consistency in instructions provided to users and a more streamlined process for the model provider.

Good support would be needed for those getting started in using the GSL model. The briefing/training session was somewhat daunting, as is usually the case with complex modelling software at the beginning. Barrie offered further training and readily available support for this study which the consultants took up. A one-on-one session working with their data, as Barrie did for the consultants, is likely to have provided a better learning experience than a short group session and /or trying to work this out from a manual.

On a commercial basis, there would need to be formal systems in place to provide this training and support. If the model became more widely used, this training and support may need to allow for the possibility of a number of users e.g. full day courses or group training. Consideration could be given to providing a one-to-one initial session (which could be costed accordingly) to ensure new users, such as consultants, have a good understanding and are not deterred, especially considering that they will be more accustomed to spreadsheet or simulation models such as Farmax or UDDER which have a very different appearance and method of use.

4.2 Simplicity of Use

For someone familiar with LP, model use is reasonably intuitive and a degree of competence can be gained quite quickly i.e. within an hour or so of practice. Data entry is relatively simple and some templates are provided for various inputs such as pasture growth, feed quality (MJME) and utilisation.

A weakness of the model is that having constructed a scenario there is no record of what data have been used. If a template is used, it would be useful to have some record of this.

The use of the Save As (PDF or HTL) option is a simple process to save results „outside" of the programme to a table, and it is also easy to build up a selection of "results" within the programme. It is recommended that if saving to a file external to the programme, the PDF option provides a tidier result. There is no option available to save the file to a spreadsheet. To compare results, printing out the various scenarios and then comparing them is likely to be the preferred approach. Additional information regarding changes to inputs and economic values would have to be added to the outputs by the practitioner. This aspect is seen as a weakness to the programme.

A comprehensive set of graphs is provided as output, with multiple graphs on the summary pages provided and larger more detailed graphs on the "Edit" pages.

4.3 User Level

Compared to Farmax, which is the main farm decision modelling programme currently used in the New Zealand context, setting up and understanding the requirements to use the GSL model is more easily learnt than the Farmax model due to the added complexity involved with Farmax as a simulation model. However, taking into account the basic differences between Farmax, which is a simulation model and the GSL model, which is an optimisation model, Farmax is able to provide more detailed results of both the financial and of the biological processes involved.

The level of expertise required to operate the model, while easier for the GSL model, is still likely to challenge most farmers who have not had previous experience with computer models. Although, as earlier stated, if a comprehensive guide was written and perhaps a help line was set up, this would encourage motivated learners to try the programme. Consultants should be able to gain a good level of competencies quickly. This would be enhanced with multiple users on different farms.

4.4 How to use the Model

Due to the different styles of model, the best way to use the GSL model is in conjunction with Farmax or a similar model such as UDDER. The GSL model is able to quickly develop the design of the optimal farming system (subject to the activities provided) but is not suitable for short term tactical management. As such, Farmax or Udder can then be used for the tactical management of the farming system through the season. The cost of obtaining and operating both systems may be a disincentive to many potential users.

4.5 Accuracy of Results

The results appear accurate although somewhat simplistic in detail. If discovering the optimal system of the farm is the main requirement, then providing the results are consistent in calculation and presentation, which they appear to be, then this simplicity is not necessarily a problem as it is the comparison which provides the main benefit.

4.6 Understandability

The letter included with the sample report stated that profit is the cash surplus for the year. Profit is a word with many meanings, so this needs to be clear to users in any documentation. Systems with different amounts of capital required may be less easily compared if optimisation is in terms of cash surplus only, i.e. the opportunity cost of capital is not taken into account. Where options require different levels of fixed capital (e.g. more cows, irrigation, drainage etc.), further analysis must be undertaken to account for differences in the cost of capital. It is not clear how the model handles inventory, depreciation, tax etc: from the report, it looks like some of these are available in the reporting, if not the optimisation.

A set of sample reports was provided. These appeared to be comprehensive and well presented, with output data reported at two weekly intervals.

4.7 Scenarios Modelled

The GSL model is able to model any reasonable scenario envisaged, ranging from System 1 to System 5 farms (DairyNZ, 2012), but it cannot model some changes to the system. These could include biophysical changes, such as incorporating cash crops into the system, or capital (lumpy) changes, such as building a second cow shed or incorporating an in-shed feeding system. Some dairy farms, particularly in Canterbury, incorporate cropping options into their systems. The inability of the model to incorporate capital into the analysis is an important weakness. As such, further analysis has to be undertaken to account for the cost of capital. The GSL model does not have the facility to transfer cash between periods to ensure seasonal purchases can be undertaken from accumulated cash.

4.8 Modelling Risk

Risk is able to be assessed through the running of various scenarios, however, from the evaluators" experience (which is limited) techniques such as "Monte Carlo" could be used to evaluate results or incorporate covariance techniques. This would need to be done in a non-linear programming model.

4.9 Suitability for Research

While there will be situations where the GSL model will be able to add information to research, it is felt that in most situations it will be more suitable to construct a „fit for purpose" model thereby being able to focus on the specific questions sought to be answered. However, the GSL model has been used comprehensively in a report compiled by DairyNZ (Howard, Romera & Doole, 2013) for consultation with the Selwyn – Waihora Zone Committee (a subcommittee of Environment Canterbury) regarding the modelling of various dairy systems changes required for dairy farms to reduce their nitrogen leaching and meet future new limitations. As the model was controlled by the developer in this work, elements such as the addition of feed pads and herd homes may have been able to be added which a „regular" user may not be able to do.

4.10 Black Box Access to run the Model

Another limitation for research organisations is the requirement for the GSL model to be linked back to the main operating system via the „cloud". This has proved to be a considerable impediment for use due to the existence of „fire walls" which all universities have and most research organisations are also likely to have. While this may not affect many users, it has been an added complication in this assessment.

The model operates from a server out of Christchurch where Jade, the most recent software developer of the GSL model, is situated. This means that web access and access to the server is required to use the model, although the developer does have a stand-alone demonstration version used for training.

University firewall restrictions make access at Massey and Lincoln Universities difficult, and this may also be true for other organisations such as MAF (MPI) and DairyNZ. Other potential users such as the larger farm consultancy businesses may experience similar access difficulties depending on their IT systems and firewall set up. Consideration could be given to developing a cut down standalone version, even just to view files and outputs from previous runs, with a facility to export/import data between the two models.

4.11 Conclusion

The GSL model does provide another useful addition to the „tool box" of farm system simulation programmes, and by itself or used in conjunction with other programmes (such as Farmax or Overseer) this programme should be considered a viable option. Subject to cost (unknown for this evaluation), if the practitioner is proficient in the construction of LP it may be easier to construct a model tailored to the farm or problem being studied, although this option may not be applicable to most users.

4.12 GSL Model Availability and Information

The functionality of the GSL model against the predetermined criteria has been the focus of this expert evaluation. However, for these findings to have relevance, the model needs to be available for people to use. For industry uptake to occur in the first place, there needs to be industry awareness of the model. It appears that awareness in the industry is relatively low and there is limited information available. If people are aware of the model's existence, they know little about it. The model is only available through direct contact with the developers.

Finding information on the model was difficult, even when there is awareness of the model's existence. Information available from a web search was limited and out of date. It appears an earlier version was released and promoted in 2002 (press articles about a release). A website was referred to in a 2002 article (www.grazingsystems.co.nz), however, this web site is non-functional. This non-functional website is also mentioned on the Jade Software site. Furthermore, the Jade Software site itself has very limited information on the model and is not a site where farm consultants or potential GSL model users would normally look for farm management software.

A brand clearly exists (GSL) and appears on the reports provided to the research panel, but the instructions were not presented in a similarly branded and well-presented document suggesting these are used only by the internal GSL consultancy team. In the absence of a web site, which most commercially available software models have, there is no obvious access to material on the model and what it does, information on costs, and how or who to contact to obtain access. Thus, while it is suggested that the model is "commercially available", in reality, its availability is limited or restricted.

It is unlikely that those unaware of the model's existence could learn of its existence except directly from the developer or one of his associates, through involvement in R&D where the model has been used by the developer in this work, or from papers and publications on work done using the model e.g. conferences, or word of mouth from others who are aware. Researchers rather than consultants are most likely to become aware of the model through these means. Yet for the model to become more widely used in industry and ultimately benefit farmers in considering different farming systems, consultants need to be made aware of the model and its capability, and it needs to be readily available for consultancy use. It appears, based on a web search, that currently only Barrie and his associates are using this in a consultancy capacity.

While this model has the potential to be fully commercial and would provide another useful tool for farm consultancy, processes, structures and information need to be put into place for the model to be considered truly commercial. The model would require a greater profile, with readily available information on what it does, the skills required to use this, costs and a person to contact if people are interested. The software needs to be easily downloaded or accessed, with a process in place for doing this. A standard set of branded and clearly set out promotional material and user instructions needs to be available to go with this software package. Thought also needs to be given to training and support requirements, and as with most models, this would need to be on-going: this could be provided one-on-one and/or on a group basis. In particular, training would be required for those starting out using the model. Currently, it appears Barrie does any training as required and provides on-going support, and in this project, he was very helpful in this respect.
On a commercial basis, it is likely that there would need to be a person with a clear training role and a more definitive process.

5.0 GSL Model Case Study Results

Each case study is described with respect to the data collected from: the recorded interviews ("The Pre-visit Interviews" section); the observations from the consultancy visits ("The Consultant"s Visits" section); the post-visit interviews and the consultant"s comments on using the GSL model for the scenarios of interest ("The Post-visit Interviews and Consultant"s Comments" section); and the consultant"s report on his evaluation of the model ("Consultant"s Evaluation of the GSL Model" section).

There were several stages to the consultancy process. The initial stages were similar for both consultants. In order to validate the model, Consultant A ran the GSL model using data from a well-known farm then used data from the case study farm. Consultant B validated the model using data for each of his case farms. In this study, model validation was interpreted as "the users having sufficient confidence in the model to accept the results as the basis for a change in strategy". In all three cases, data from the 2011/12 season were selected for the base farm to model the scenarios from since good data were available, these data represented a whole year of operation, and this was a year in which was relatively typical. Since this was a good year, fewer pasture supply constraints were experienced when running the model over the year. Once the consultant considered that the case farm was realistically represented by the GSL model, he considered the model valid. He then ran sets of scenarios and sensitivity analyses to further test his confidence in the model and to begin the process of analysing the issues of concern to consultant and client for that farm. However, the process for each consultant differed slightly from this point. This process is described in "The Consultant"s visits" section for each case.

5.1 Case Study A

Case Study A involved a consultant and client, both experienced with using farm management models as an aid to farm planning and management.

5.1.1 The Pre-visit Interviews

Consultant A described the way in which he evaluated systems for his clients using his own experience, data held by his firm and simulation models. He had considerable experience with models and explained that he used UDDER and Farmax Dairy regularly. His exposure to LP was limited, but was likely to be sufficient for him to be well prepared for the briefing session with the model developer. For the GSL evaluation, he had chosen a client who was familiar with the modelling process, had considerable reliable data and was keen to explore a particular issue that had been encountered as a result of recent management changes on the farm.

Client A had a 500[6] cow herd on a milking platform of 155ha. He also had a run-off a short distance away. A K-line irrigation system for the purpose of increasing summer pasture growth rates was the most recent introduction to the milking platform.

The client had also had considerable experience with farm simulation models, and said that there were comprehensive physical and financial data available for modelling. He also described the farm structure, aims and objectives, and emphasised that their aim was to utilise pasture as effectively as possible. He was particularly concerned to find the best possible match between feed demand and feed supply, and to this end, he and his sharemilker had put considerable effort into finding the stocking rate and calving date that best fitted the goal of matching feed demand and supply. Cow numbers were constrained by milking shed capacity.

He had changed to an earlier calving date and this had the unanticipated effect of compacting calving, resulting in feed deficits in early lactation necessitating the purchase of ("expensive") feed. Arising from these feed deficits were quite specific questions that the client wanted to explore with the model. The questions he wanted to ask included: Had they achieved the best match of feed supply with feed demand with their recent changes in calving date? Should calving be changed again (to a later date) given the high level of management input that was required to move to an earlier calving date? The consultant and his client both agreed that a good outcome would be "something that gives us more confidence and puts some numbers on our system, not just generic ones. What does it mean for our system?"

5.1.2 The Consultant's Visits

At the first visit, which was also attended by the sharemilker, the model was run remotely on the consultant"s laptop[7]. The consultant explained that he had modelled the current 2011/2012 season previously with the GSL model using the client"s farm data and, with the client"s agreement, would use that as the basis for further analysis. At first, discussion centred on the structure of the model, including the following concepts, which were in contrast to those used in models with which the client was familiar.

- The way in which the model dealt with calving patterns. The client and sharemilker were used to the concept of "mean calving date", but for the purposes of the LP, a set of "calving regimes" (calving spread predicted from a fortnightly milk production profile) had been incorporated into the GSL model. This was the subject of some discussion at the time. Later both consultant and client would comment on this aspect of the model.
- "Total milking cow numbers" was used in the model rather than "stocking rate".

The model uses a "normal" milk production curve based on their own farm data to calculate intake, and this can be constrained if feed is limiting based on pasture cover and growth rate.

- Maximum and minimum average pasture cover levels were constrained to the levels practised on the farm.
- Purchase of off-farm supplements expressed as kilograms of dry matter (kg DM). In the model all supplementary and concentrate feed is purchased generically as kg DM, and there is no distinction between the various forms that the feed might take.
- The concept of a "sustainable" system as being one that must have the same level of resources (say pasture cover, milking cows, replacement stock) at the end as at the beginning of the year.
- The model does not allow for extra capital investment (such as would be required to extend the milking shed to cater for increases in milking cow numbers)[8].
- The model tries to work cost-effectively towards the highest level of operating result (the consultant"s term for gross returns less user-defined variable costs which others might term total gross margin).
- The MVP information provided by the feed diary component of the model as feed became limiting, the opportunity cost of the feed increases.

The model was then run using current pasture growth rates to evaluate three different calving regimes and three different levels of cow numbers (with milksolids payout fixed at $5.50/kg MS). The outcome showed that the current calving regime was close to optimum, but indicated that it would be profitable to increase cow numbers. However, both the client and the sharemilker agreed that they would not wish to do this in the meantime because of the capital required for shed expansion and the increase in milking time. An upper constraint on cow number was therefore established at 520.

During the discussion, the client and sharemilker identified a potential strategy of carrying the number of cows suggested by the model during the winter and then varying the immediate post-calving cull number according to expected payout and pasture growth rates. With this in mind, the client requested further testing to explore scenarios around milksolids payout and the cost of supplementary feed. He also asked the consultant to increase model cow number to 550 to see if there were any "diminishing returns". The client"s time was limited at this visit so a subsequent

[6] At the time of the visits the farm was milking 480 cows.
[7] The consultant used his cell phone as a "hotspot" to access the internet wirelessly from his laptop.

visit was arranged.

At the second visit, which the sharemilker was not able to attend, the results of the requested analyses were presented and summarised (See Appendix II for the consultant"s full report). Results showed that:

- The optimum calving pattern (identified as slightly later than the current one) gave the best outcome and was not particularly sensitive to payout. However at lower cow numbers (current levels or fewer), the current (slightly earlier) calving date would give a similar financial outcome.
- As herd size increased, returns increased. This was tested at 550 cows (even though it was beyond acceptable cow numbers) as the client and the consultant were both interested in the stability of the model at that level. The result indicated that returns would continue to increase with herd size.
- In lower payout years ($5.00/kg MS) the model could not justify purchasing extra feed after calving, but could do so in higher payout years.
- With lower cow numbers it was difficult to control pasture cover to the maximum cover specified in the model.

The GSL modelling exercise identified that higher cow numbers offered increased flexibility. It provided the opportunity to cull more heavily immediately after calving if a lower payout was anticipated, and retain more cows to take advantage of a higher payout, even if it meant purchasing feed.

5.1.3 The Post-visit Interviews and Consultant's Comments

In their final interviews, both the consultant and the client said they believed the model produced useful results as described in the consultant"s report to the client (Appendix II). They each attributed this confidence in the model to the fact that they had worked together using models before – "we put in some data to road test the model" (Client A). The fact that model results were stable over quite wide variations in cow numbers increased their confidence in the model.

The model concepts of calving regimes and sustainability, and their implications were discussed, and both the consultant and the client recognised that they would influence implementation of strategies. The consultant and client both noted the fact that the GSL model arrived at a solution more quickly than the other models they had used. The client commented that he ran a "marginal" enterprise – that is, he expected that each additional input (especially bought-in feed) should return more in additional milksolids revenue than the cost of the additional input. So the concepts of "optimum" and "marginal revenue versus marginal cost" which underpin the LP model were useful to him.

[8] Here it was noted that if the client was interested in increasing a fixed resource (such as cowshed and laneway extensions), the model would provide opportunity cost information to assist in the calculations but a full analysis was beyond the scope of this project.

The client also first identified a further objective, that of “repeatability” at the post-visit interview, saying that he wanted to put systems and strategies in place that were able to be used successfully in successive years without the need for continual modification. Both the client and the consultant felt that, because resources were required to be the same at the beginning and end of the year, the strategies suggested by the model output fitted with the client‟s objective.

The consultant made some important points with respect to the GSL model and its results for this farm in his report to the client (Appendix II), as shown in italics below.

“The GSL LP tool has provided a useful insight into the interaction of stocking rate, calving date, payout and price of supplements. Some of these outcomes confirm a natural pattern of thinking and the other outcomes provide a challenge for further consideration”

and

“The clients have expressed a need to keep the operating system uncomplicated and repeatable. The capping of herd size is in part due to this, but requires no further changes to infrastructure”

The consultant also emphasised the following four points in relation to the results generated in the model:

- *At 450 and 480 cows the amount of supplement required was minimal. This keeps the practise of feeding cows relatively straightforward.*
- *The model described a conflict with 450 cows, the lowest herd size trialled in trying to keep average pasture cover under 2500 kg DM/ha. This suggests 450 cows in most seasons would provide some under stocking-based issues or management challenges.*
- *At 520 cows and an early calving date there was some instability in the model – suggesting it was very sensitive to early lactation feeding levels. The clients reflected that this is consistent with their experience in the current season (12/13). With a similar herd*
- *size and a spring feed deficit, it brought up a management conflict where it was considered uneconomic to fill the deficit.*
- *At a higher milksolids payout, the model would encourage a higher stocking rate and higher inputs, but the benefit of this with payout volatility presents some concerns.*

He concluded that:

- *Given the above, and attached reports, I would suggest the optimal peak cow number is around 480-500 cows, calving at the start of August, requiring modest feed inputs, but able to deliver an optimum economic result in a low to medium payout environment.*
- *In a higher payout environment, the early August calving date remains appropriate, but the question could be asked on herd size. The larger herd size would deliver the higher gross margin, but brings risk with payout volatility.*

The consultant also obtained his client‟s views of the model which are summarised below.

- *The information from this software tool, and our collective interpretation increases our confidence to change to a later calving date.*
- *We have identified that an easy "lever to pull" given an early August calving date and seasons with higher milk payment would be to retain more cows. This could be as simple as culling 20 fewer cows. This allows the system to be kept simple and repeatable, yet responsive*
- *Changing herd size requires capital expenditure. Up-scaling to 550 cows would require a new cowshed and possible changes to other aspects of farm infrastructure. Analysing the costs and benefits of this is outside the scope of this report.*
- *However the 550 cow information does give confidence that more cows should be carried in any given single season.*
- *The client stressed that a higher input system runs the risk of other managerial and environmental challenges.*
- *The tool was used with 20c and 40c/kg DM options for the cost of strategic supplements.*
- *The 40c cost was deemed more reasonable.*
- *The clients, in consultation with their sharemilker will take a stepwise progression in response to this information. Their calving date will be shifted from mid-July to early August.*

5.1.4 Consultant's Evaluation of the GSL Model

The consultant also provided a report on his evaluation of the model (Appendix III), including a comparison with UDDER and Farmax Dairy and evaluative comments on the model.

5.1.6 Comparison with other models

Table 1 shows the consultant"s comparison of GSL model output with UDDER output. Actual farm production for the 2011/2012 year was 187,253kg milksolids plus calf milk. He noted a difference in pasture utilised between the models but could not say whether one was more accurate than the other, and was comfortable with the result.

Table 1: Comparison of GSL model and UDDER model outputs using Case Farm A data for 2011/2012 year

	GSL Model	UDDER Model
Milksolids	199,000 incl calf milk	186,261 + calf milk
Cow Numbers	488	465
Pasture Yield t DM/ha	14.3 – utilised	12.4 - eaten
Supplements	148 t DM	147 t DM
Crop	50 t DM	40 t DM

The consultant offered some direct comparisons between the GSL model and UDDER noting that the GSL model constructed a model faster. He would have greater confidence in the UDDER results, but believes that the GSL model would come up with a similar answer in a shorter time frame. UDDER has a factorial optimisation routine that delivers a matrix of solutions and works in a similar manner to the GSL model. However, UDDER is easier to report from as the GSL model requires manual operating and thus more operator time. UDDER can also be used as a monitoring tool so can be used to verify progress against a plan. This is a useful feature for the GSL model to consider incorporating. UDDER does not track prior runs unless these are specifically saved as a different file, whereas the GSL model tracks prior runs which the consultant considered a good feature of the GSL model.

The consultant also compared the GSL model with Farmax Dairy. The GSL model established a model more quickly than Farmax, and was faster at analysing alternative options and providing information on optimal farm system requirements. In contrast, analysing alternatives and providing information would be a manual routine in Farmax. The GSL model does not appear to provide a comprehensive financial analysis or report so preparing results for presentation to a client would require further work on alternate software. In contrast to the GSL model, Farmax does not track prior model runs, and would require manual saving of different files to allow the same style of operation.

5.1.7 Other points noted by the consultant

The consultant felt uncomfortable about the way in which a calving pattern is established based on a milk production profile and did not consider this an intuitive way of thinking about calving patterns. He would have preferred to have entered a calving pattern.

The consultant noted that the manner of using a reserve supplement[9] to ensure there are more viable outcomes means care is needed to ensure that this is correctly accounted for in the outcome (see Appendix III, Issues, for an explanation). He also considered that all three tools lack a "nutrition" function[10] that accounts for feed components other than energy. Note that both UDDER and Farmax Dairy are fundamentally energy based systems analysis tools as is the GSL model.

The consultant also discussed the use of the GSL model as an addition to the "tool box" (Appendix III) and concluded that the GSL model was a "niche tool" to help clients identify system improvements. He considered the question of "cost of time and cost effectiveness for client". Compared to the use of other models, he concluded that if the analysis is straightforward, the GSL model would be more cost effective than other models. If more analysis was requested, the GSL model would be more expensive because of the extra time required to set up a more complex report method using alternative software such as a spreadsheet or another model. Other models provide more information and indices than the GSL model. He, personally, was unlikely to add the GSL model to his tool box as he and his clients were already familiar with his current tools and his time was already fully occupied meeting his clients" current demands using these tools. He also reasoned that both the time cost of using the GSL model for anything other than straightforward problems, and also the time and monetary cost of buying another programme were detractions from using the GSL model.

[9] The "reserve supplement" concept is explained in more detail in Appendix III
[10] Presumably whereby components of feed other than energy, especially in supplements and concentrates,

can be taken into account in the analysis.

5.1.8 Suggestions for GSL model improvement

The consultant offered a number of suggestions as to ways in which the model could be improved. Each of these is explained in more detail in Appendix III: Consultant A: GSL Model Evaluation.

- Improvement to the windows and navigation would help the user to set up, present and save runs as they are completed, and thus improve demonstration to clients. In particular, windows and drop down boxes obscured each other.
- A monitoring facility that would enable the user to enter actual performance against the plan generated by the GSL model would enhance the software to a level where extension people could use the tool.
- Simple reports to present both tables and graphs for use in the consultants" reports or for active demonstration to the client would be useful.
- It would be more conceptually acceptable to be able to engineer the calving pattern to closely represent real situations.
- A sensitivity template would have greatly helped in the case study. Since the model is a specialist LP tool, a sensitivity analysis component with a spreadsheet output could be developed. This feature, together with some reporting enhancements, would be a very powerful way to show the system"s sensitivity and management options in an environment of fluctuating input costs[11].
- The training programme for someone less experienced would need to be more extensive. A full training requirement might be at least one full day with a follow up day to verify full and correct use. Time would be needed initially to work through the concept of LP and ensure the participants understand its use and limits.
- Incorporating a nutrition function that accounts for feed components other than energy as a basic function in the GSL model would be useful. The industry is increasingly looking for information on nutritional implications when making diet decisions. A feed library could accommodate nutritional information which could then be used to verify points in the plan where nutrition may not match production expectations.
- Where financial aspects are concerned, the model does what it is designed to do, which is to demonstrate marginal changes in economic performance. A detailed financial plan attached would be useful. The model may already have the ability to link to a spreadsheet, but users need to see and use this facility to extract further value.

[11] For example, as the price of milksolids increases so too does the cost of supplements and concentrates.

5.2 Case Studies B and C

These two case studies involved the same consultant (Consultant B) so only one pre-visit interview with the consultant was undertaken. The consultant"s pre-visit interview and his modelling process were undertaken prior to the farm visit. The information related to these are described prior to the individual cases since this is relevant to both Case Study B and Case Study C.

The pre-visit interview for each client, the consultant"s visits and the post-visit interviews are described separately for each case study. The consultant"s observations on the model are summarised after the description of case studies.

5.2.1 The Consultant's Pre-visit Interview

Consultant B gained a science qualification, which was followed by a period of business employment, study for a Massey post-graduate Diploma in Rural Studies and employment in a farm management consultancy business, before establishing himself as a sole consultant. He makes considerable effort to keep up-to-date through participation in professional associations and attending conferences. In particular, he follows the three-leaf grazing management philosophy of Professor Danny Donaghy of Massey University (Donaghy & Fulkerson, undated).

The consultant has used a range of modelling software to explore opportunities for his clients. He was aware of LP as a possible way of exploring opportunities, and had heard the GSL model developer present at a conference. A cursory attempt to follow up on this had not resulted in any developments until this study.

His usual consultancy process with a new client starts by collecting data from the client for a recent average season and using those data and modelling these data in an UDDER model. He then uses the model output to benchmark cow and pasture performance against UDDER model results for other clients, while looking for effective current and potential strategies. He uses the UDDER model to help him explore issues associated with grazing management, crop agronomy, cow genetics and nutrition while observing their effect on financial performance during this process. He then establishes future strategies, together with targets and management practices to achieve them. This begins with ensuring that the pasture management is effective in providing enough energy to the cows in the system, as well as using supplements and urea to provide energy as the need and opportunity arises. The next steps are to look at the financial effects, feed conversion efficiency and aspects of genetics. His objective is to ensure that each client "continually grows their business".

5.2.2 The Pre-visit Modelling Process used by Consultant B

In his post-visit interview, Consultant B described the modelling process used with the GSL model and the UDDER model prior to visiting his clients. This is included here to assist understanding of the process subsequently used for Cases B and C, as described in the following sections.

In his pre-visit modelling, the consultant ran and validated the GSL model using data for the 2011/2012 season as described at the beginning of Chapter 5. The resulting optimum solution for this season was then used to identify “critical parameters” (i.e. factors constraining production), and these factors, together with other constraining factors the consultant had identified from his own experience, formed the basis of a series of sensitivity analyses and scenarios which were worked through using the GSL model with assistance from the model developer. The results from these GSL model analyses were then explored using the UDDER model to test that the solutions were viable. These scenarios and their results were then presented to the clients in the UDDER model output format.

Consultant B commented that using a computer model with clients was impractical because broadband access in this locale is slow and he did not consider that it was reliable. While this would be a logical reason not to use computer models outside the office, it later became apparent that he did not use computer models directly with his clients anyway. His consultancy process is to present them with pre-run results and his clients are accustomed to this style of consultancy.

5.3 Case Study B

Case study B involved a consultant (Consultant B) who was experienced in the use of models and a client (Client B) who relied on the consultant to do all the modelling work and present the results and their interpretation. In the interview before the consultant visited his client, the consultant said that he believed that Client B was likely to be interested in changing his system to fewer, higher-performing cows in an effort to lift profitability. This opportunity was possible because the farm has a very low empty cow rate so there was potential to cull poorer performing cows. A second opportunity was to find the optimum area of maize to grow for silage.

5.3.1 The Client Pre-visit Interview

The client runs a high-producing, 100 ha milking platform with 275 milking cows on a seasonal supply farm. Replacements are grazed off from November. Turnips are grown for summer feed and four hectares of maize is grown for silage. The feeding regime also included a moderate amount of concentrates, usually in the form of PKE or a substitute when PKE was not available. The cows are of high genetic value as AI has been used on the farm for 60 years. A manager is employed on the farm, with a new manager due to start in the coming season.

The farm falls naturally into two halves. The “home” block is closer to the dairy shed and has higher levels of soil fertility, having been farmed under the client‟s management for much longer. The second half, purchased more recently, has a higher sand content and is naturally less fertile. It is mainly used for daytime grazing, with the home block being used mainly for night grazing.

The client has employed the consultant for five or six years. The client sees the strength of the consultant‟s advice as being mainly in the area of feed management (quality and quantity), including advice on grazing and the use of conserved feed and bought-in supplements and concentrates. The consultant can use the UDDER model to model feed requirements when production is known, or conversely, to model production levels from feed when feeding levels are known.

The client had no particular problem in mind prior to the visit. However, he was concerned that consultants and researchers had suggested increased cow numbers over the years. Now that farmers are buying in more feed and the cows are doing better than 10 years ago, this suggests that they are not taking full advantage of the genetic make-up of their cows. He also considered it was important to keep in mind the costs of feeding extra cows when that feed could be given to fewer cows and have them produce more.

5.3.2 The Consultant's Visit

The visit to the farm was incorporated into a regular consultancy visit, including a farm walk to assess the state of the pasture and the cows. The new manager was there to gain familiarisation with the farm and its management. The consultant planned to use the discussion after this farm walk to consider the issues that had arisen out of the GSL model analysis. He had prepared some notes from the information that the analysis had provided (see Appendix IV). In addition to his usual observations on cow condition and pasture status, he used the farm walk to make observations on the utilisation of supplementary feed. Low utilisation of supplementary feed was a key finding identified in the GSL model analysis which had not been anticipated.

Discussion centred on the results of the GSL model and subsequent UDDER analysis. The consultant explained that the model was validated on the basis of the 2011/2012 farming year which had atypically high summer pasture growth rates and higher pasture quality than usual. The results of the optimisation showed that 2011/2112 per cow performance was good, at nearly 400kg milksolids/cow. More pasture silage and maize silage than usual was harvested. Pasture, whether grazed or conserved, was of high quality since the "Danny Donaghy" principles had been applied. The consultant and client believed that this high quality pasture was consistent with what had actually happened.

The GSL model had indicated that farm performance was sensitive to four key parameters:

- Pasture harvested, whether grazed or for silage: The model showed that higher returns were achieved when maize silage was purchased rather than grown on the farm, primarily because of the area out of pasture when maize was grown.
- Turnip yield: To be included in an optimal plan, the turnip yield needed to be higher than 7t DM/ha. A lower yield than this is usually achieved because turnips are grown on the poorer side of the farm, and the consultant suggested that this would mean that the turnips should be grown on the more productive side of the farm.
- Nitrogen response: Other than to be noted, this parameter was not discussed any further.
- Utilisation of supplements and concentrates: The model indicated that around 30% of the supplements and concentrates fed were not being utilised.

The consultant explained that the model identified the highest gross margin was where maize silage was purchased off the farm and the land was retained in pasture. However, he pointed out that the high grass production peak occurred at the time the land was taken out for silage so it was convenient, in terms of pasture management, to grow maize.

The consultant discussed the implications of growing turnips only on the higher-fertility side of the farm, including their contribution to the fibre component of the cows" diet. He suggested alternative ways of achieving pasture renovation if turnips were not grown. He identified that

further model analysis could include splitting the farm in two (to account for the different performance levels on two sides of the farm) and letting the model identify the best option.

Improving the poor utilisation of supplements seemed to offer the best immediate possibility for an improvement in performance. There was considerable discussion about methods of feeding supplements in a way that reduced wastage, including building a feed pad or installing an in-shed feeding system. The attributes of each were discussed, including their costs and potential returns.

The consultant identified issues relating to increasing per cow production which was the other factor the client was interested in (see the pre-visit interview), and which would require further study of cow genetics including an analysis of the client"s LIC records.

Table 2 shows the UDDER model outputs which resulted from using GSL model outputs as UDDER model inputs, particularly utilisation of supplements (represented by lower input levels) and improved cow genetics (represented by higher milksolids production). The UDDER model results that Consultant B showed his client indicated that improved utilisation of supplements would result in an increase in margin of nearly $12,000/year, which could be used to finance the purchase of an off-paddock feeding system. Alternative feeding systems and management would be required for increasing per cow production which the GSL model indicated could eventually return more than $60,000/year more.

These issues, which required considerable thought, would not be resolved within the timeframe of the project as the client was taking time away from the farm immediately following the visit. However, the client did discuss them in the post-visit interview (see next section).

Table 2: UDDER Model Results for Case Farm B based on GSL Model Results									
	Whole farm			Per Cow			Per ha		
	2011 - 2012 season	Improve supplement utilisation	Improve cow genetics	2011 - 2012 season	Improve supplement utilisation	Improve cow genetics	2011 - 2012 season	Improve supplement utilisation	Improve cow genetics
Farm Area (ha)	100	100	100	0.397	0.397	0.397			
# cows	252	252	252				2.5	2.5	2.5
Production (kg MS)	99,367	99,259	110,725	394	394	439	994	993	1107
Concentrates (tonnes)	140	111	149	0.56	0.44	0.59	1.4	1.1	1.5
Silages (t DM)	103	90	142	0.41	0.36	0.56	1.0	0.9	1.4
Nitrogen (tonnes N)	14.8	14.8	15	0.06	0.06	0.06	0.148	0.148	0.150
Pasture harvest (kg DM)	1,080	1,120	1,120	4.29	4.44	4.44	10.8	11.2	11.2
Total Feed (kg DM)	1,323	1,321	1,410	5.3	5.2	5.6	13.2	13.2	14.1
Percentage grass	82%	85%	79%						
Feed Conversion (kg DM/kg MS)	13.31	13.31	12.74						
Milk price/kg MS ($/kg MS)	$6.00	$6.00	$6.00						
Milk Income ($)	$596,202	$595,554	$664,350	$2,366	$2,363	$2,636	$5,962	$5,956	$6,644
Cow Milking Costs ($)	$226,800	$226,800	$226,800	$900	$900	$900	$2,268	$2,268	$2,268
Concentrates ($)	$49,098	$38,819	$52,024	$195	$154	$206	$491	$388	$520
Silages ($)	$18,019	$15,959	$25,245	$72	$63	$100	$180	$160	$252
Nitrogen ($)	$26,550	$26,550	$26,964	$105	$105	$107	$266	$266	$270
Agistment ($)	$27,222	$27,222	$27,222	$108	$108	$108	$272	$272	$272
Total Feed costs ($)	$120,889	$108,550	$131,455	$480	$431	$522	$1,209	$1,086	$1,315
Margin	$475,313	$487,004	$532,895	$1,886	$1,933	$2,115	$4,753	$4,870	$5,329

5.3.3 The Post-visit Interviews and Consultant's Comments

The client found himself in a dilemma regarding the practice of growing turnips and maize for silage on the farm. The practice of growing turnips began as part of a pasture replacement policy. They were usually grown on the less fertile part of the farm, and some of the turnip crops had been poor and others had to be re-sown because of poor germination. The model had indicated that they should only be included if the yield was good, but he did not want to sacrifice good pasture in order to grow a good crop of turnips.

A similar dilemma arose over growing maize. Model results suggested it would be better to grow maize off the farm. There was a differential in yield between growing maize on the good and the poorer sides of the farm. The trade-off was that in order to get enough maize he would have to plant a bigger area. Applying effluent enhanced the potassium status of the soil and contributed to crop yield – making growing maize on the farm more attractive. The trade-offs for each crop needed to be clarified further, and he intended to discuss this with his consultant and his manager.

The other issue the client had considered important was supplement utilisation. The consultant had recognised that if the goal was to reduce cow numbers and produce more from each cow, it would be necessary to reduce losses from supplementary feeding. He proposed an off-paddock feeding system as a solution. While the client recognised the issues (cost of wastage versus cost of an off-paddock feeding system) he felt that installing such a system was not a consideration for him.

The consultant explained that the modelling process outlined in "the pre-visit modelling process" section was the means by which he gained confidence in the use of the GSL model. He said that he wants to be sure that appropriate constraints were in place to model the actual system realistically. An example that made him feel uncomfortable was when the model was inadequately constrained and results suggested feeding a large proportion of the diet as maize silage, which he thought would be nutritionally unsound practice. He recognised the need for careful specification of the model components, but said that was true of all models, not just the GSL model or LP.

The model developer had given further tutorial assistance and expertise on request during the modelling process. The consultant explained that working through issues directly with the developer would be a more efficient use of his time than learning the detailed workings of the GSL model since he was unlikely to use this model in future.

The consultant also explained his views on the role of the consultant in the use of models. He believed that only a few of his and other consultants" clients would be interested in the workings of models such as UDDER and Farmax. The consultant had found that very few farmers (whether his clients or not) were interested in running models themselves, much preferring to have the consultant enter data and extract the necessary information instead. He considered that most farmers were confident in the results obtained by their consultant and were not interested in how these models worked. Since the workings of the model are not of interest to the client, the consultant and client can focus on discussing the practicalities of the model findings.

5.4 Case Study C

This case study involved the same consultant as Case Study B, but a different farmer client. The information contained in the "Case Studies B and C" section applies to Case Study C. The client in this case was described by the consultant as a high-intensity dairy farmer with high levels of financial commitment and very high levels of livestock performance. The client farms an intensive, high performance operation on highly fertile land. The farm relies heavily on purchased concentrates, and management strives to make this operation as efficient as possible.

5.4.1 The Client Pre-visit Interview

The client described his farm as carrying nearly 700 cows on a milking platform of about 150 to 160 hectares, with less grazing area available in spring if they plant maize. He described a farm which is fairly intensively run, with a high stocking rate and a high level of supplements. Peak numbers are milked for only short periods as there is a split-calving system. Four hundred and fifty cows are milked through spring; the winter herd is dried off by February, and 250 cows are calved in the autumn. About 300 cows are milked for quota milk through the winter, including some late- calving spring herd cows through June and July depending on pasture availability.

The farm uses 2t/cow of forage supplement, in the form of maize silage and pasture silage with some barley straw. About 20 hectares or 400-500t of maize silage is grown on the milking platform. More maize silage is grown on the drystock block and some is purchased from other growers. Pasture silage is made on the drystock block and on leased land. One tonne of concentrates/cow is also fed, mostly to milking cows. The concentrates consist mainly of PKE, but last year included soda grain.[12] The dry cows stay nearby on river accretion land and are fed supplement. Staff feed supplements on most days of the year.

The client explained that the consultant visits every five or six weeks. The client sends the consultant data on feeding levels, changes in cow weights and production levels. The consultant processes those data through his software (he is currently using UDDER and CAM Dairy) and during the visit uses the output to fine-tune the diet on the basis of protein or carbohydrate content, having looked at cow condition and pasture residuals. Discussion about feed management takes up about half the visit and the remainder of the time is spent on financial matters. The client does not become involved in using any of the computer models.

Prior to this interview, the client had not been fully briefed about the GSL model and so had not thought about what issues it could address. He considered that a good outcome for him would be more accuracy in supplementary diet formulation that would reduce his feed costs. After the first visit, having been briefed about the model, he was keen to explore autumn calving dates.

[12] Caustic treated wheat.

5.4.2 The Consultant's Visits

During the first visit, time was spent on the farm in a regular consultancy visit, assessing cow condition, grazing management and pasture residuals for both herds. A discussion followed during which output from UDDER was used as the basis for revision of the current diet, the idea of using the GSL model was introduced and some data were clarified. The second visit was devoted to the results of the range of GSL model analyses that had been carried out by the consultant. The consultant demonstrated LP using the visual model shown in the following photograph.

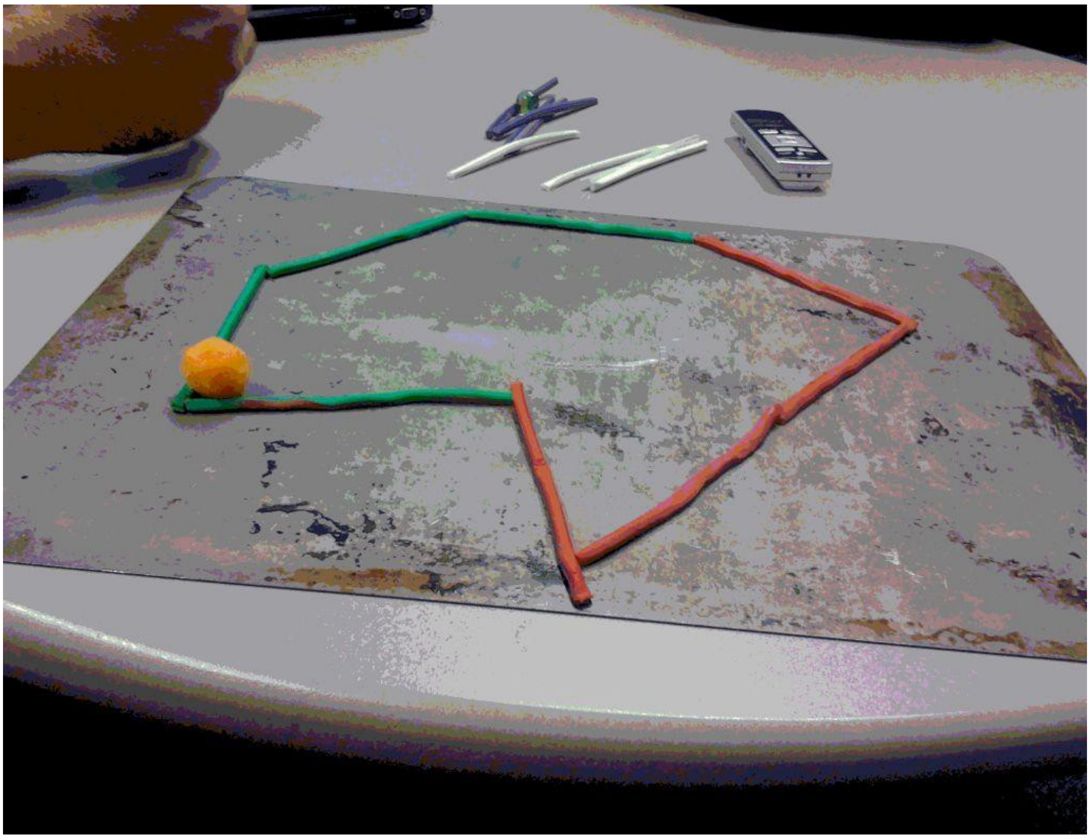

Photo 1: Visual model of LP constraints and optimum-seeking

The green and red lines (made from plasticine) represented hypothetical linear constraints and the orange ball travelled around looking for an optimum. The consultant explained that he was interested in finding out how close to (or far away from) optimum the business was operating. The consultant also explained that, because the farm was operating close to what he perceived as the biological limit (producing 120% of cow bodyweight as milksolids), he was interested to see whether the GSL model analysis would identify other issues, particularly ways to improve the system.

Table 3 shows the UDDER model results which resulted from using GSL model outputs as UDDER model inputs and using 2012/2013 pasture production data to model the results of two possible changes to the system: increasing milking cow numbers and changing autumn calving date. The first column shows the results for current milking cow numbers and provides the basis for comparison, demonstrating the already high levels of production achieved on the farm. When the GSL model selected cow numbers, it selected 123 more cows and the margin increased by about $73,000 as calculated by the UDDER model and shown in Column 2. When the model selected the autumn calving date, it was found that a slightly earlier date would lead to an improved margin of about $5,000 (column 3). The GSL model was also used to run sensitivity analyses for three key parameters – winter milk payout, the cost of concentrates and the variable cost of running cows.

The consultant said that the modelling showed only a small margin in favour of producing winter milk even though he had used parameters quite specific to the client"s farm (e.g. double peaking of winter milkers, high winter pasture growth rates and high ME for winter pasture). This led to a discussion about factors that were difficult to quantify for the purposes of the model and that knowing and understanding the system is important when interpreting model outputs.

The consultant noted that the cost of concentrates impacts on earnings "from feed conversion". At the high levels of per cow production being sustained on this farm, it was necessary for cows to have protein supplements in their diets. The GSL model did not allow for the protein content of concentrates so, while protein added to the cost of concentrates, it needed to be accounted for outside the model (see Appendix V).

Table 3 also shows that, even at milksolids returns as low as $6.00/kg MS, the model would find it more profitable to run another 123 cows. However, this number was highly sensitive to the level of variable costs/cow. At higher variable costs, the model ran fewer cows, and at lower variable costs it ran more cows. Both the client and the consultant agreed that the per cow costs of feeding and milking cows in this system were only slightly variable over quite a wide range[13]. However, if cow numbers were to rise by (say) 20%, the increase in such costs would be noticeable

[13] An example given was of milking shed costs – electricity and detergent costs hardly varied at all as cows milked through the shed rose and fell during the year. A similar observation was made about the cost of feeding supplements and concentrat

Table 3: UDDER Model Results for Case Farm C based on GSL Model Results									
	Whole farm			Per Cow			Per ha		
	2012 - 2013	GSL opt 1	Early autumn calving	2012 - 2013	GSL opt 1	Early autumn calving	2012 - 2013	GSL opt 1	Early autumn calving
Farm Area (ha)	145	145	145	0.208	0.177	0.177			
# cows	696	819	819				4.8	5.6	5.6
Production (kgMS)	449,479	512,725	513,090	646	626	626	3100	3536	3539
Concentrates (Tonnes)	1,520	1,788	1,781	2.2	2.2	2.2	10.5	12.3	12.3
Silages (TDM)	1,414	1,898	1,889	2.0	2.3	2.3	9.8	13.1	13.0
Nitrogen (Tonnes N)	28.8	28.8	28.8	0.041	0.035	0.035	0.199	0.199	0.199
Pasture harvest (kgDM)	1,929	1,914	1,929	2.772	2.337	2.355	13.3	13.2	13.3
Total Feed (kgDM)	4,862	5,599	5,599	7.0	6.8	6.8	33.5	38.6	38.6
Percentage grass	40%	34%	34%						
Feed Conversion (kgDM/kgMS	10.82	10.92	10.91						
Milk price/kgMS ($/kgMS)	$6.00	$6.00	$6.00						
Milk Income ($)	$2,696,874	$3,076,350	$3,078,540	$3,875	$3,756	$3,759	$18,599	$21,216	$21,231
Cow Milking Costs ($)	$238,000	$280,000	$280,000	$342	$342	$342	$1,641	$1,931	$1,931
Concentrates ($)	$714,215	$840,290	$837,128	$1,026	$1,026	$1,022	$4,926	$5,795	$5,773
Silages ($)	$424,144	$569,265	$566,608	$609	$695	$692	$2,925	$3,926	$3,908
Nitrogen ($)	$43,209	$43,209	$43,209	$62	$53	$53	$298	$298	$298
Agistment ($)	$202,876	$238,556	$241,295	$291	$291	$295	$1,399	$1,645	$1,664
Total Feed costs ($)	$1,384,444	$1,691,320	$1,688,240	$1,989	$2,065	$2,061	$9,548	$11,664	$11,643
Margin	$1,312,430	$1,385,030	$1,390,300	$1,886	$1,691	$1,698	$9,051	$9,552	$9,588

5.4.3 The Post-visit Interview and Consultant's Comments

The client explained that during the pre-visit interview he did not know what to expect from the GSL modelling exercise. He and the farm manager had been considering issues such as whether there would be an advantage in moving autumn calving dates earlier, whether winter milk production was viable for them and whether fewer cows could be run to advantage. The GSL model analysis confirmed that earlier autumn calving was an option that might give a slight improvement. They were preparing for mating in June 2013 for the 2014 autumn calving and are now planning to start one week earlier. While the change had already been considered, the results of the analysis had given them the confidence to change.

The client had previously questioned whether winter milk production was still a good option for them and was now confident to continue with this option, even though the margin was a narrow one. Reducing (or increasing) cow numbers had also been considered. The consultant, client and sharemilker were confident that, for reasons not necessarily reflected in the model, present cow numbers seemed to be a better strategy than the alternatives. The client reflected that once they became aware of what kind of information the programme was generating, and how it could be interpreted, it was quite a useful process to have undertaken.

The client noted that some changes suggested by the analysis arose from issues that were difficult to quantify and which he felt could not be adequately modelled by the GSL model. It appeared that these issues could be explored further given some careful specification within the model, but this was also beyond the timeframe of the study.

The consultant considered that it was necessary to have a good understanding of practical systems issues so as to put in place constraints in the model that matched reality. One example was that the GSL model results recommended feeding large quantities of feed at times, and at rates, that he did not consider appropriate but he found it difficult to set constraints to reduce supplement use to appropriate levels at those times. He recognised that such cautions apply to most models – no more to the GSL model than to any other.

The more general comments from the post-visit interview and consultant"s comments for case study B also apply to case study C since the interview with the consultant for Client B and Client C were conducted simultaneously.

5.4.4 Consultant's Evaluation of the GSL Model

Key points from the consultant"s report on the evaluation of the model are summarised below (see Appendix VI for full report).

- Web-based systems that rely on good internet access are not particularly appealing to the consultant since he operates in areas with limited internet access.
- The model is easy to use and intuitive. Entering data was simple, but relied on the user having a good understanding of energy balances, animal characteristics and grass growth profiles for the farm.

- The model relies heavily on farm information. For the model to work successfully, the consultant must ensure the appropriate data are collected from the farm. However, he believes few farmers are really interested in the workings of the model after the first session or two, and would be reluctant to commit to collecting such data on an on-going basis.
- The approach was valuable as an audit in that it raised questions about some of the standard responses and strategies used on the farm. For example, on Case Farm B, improved genetics and improved supplement utilisation seemed to provide the biggest gains. However, such improvements would require further physical and financial assessment of capital investment in different feeding systems.
- The GSL model "seems to drive feed profit through optimising the cost of energy and maximising feed conversion". At high levels of per cow performance, the system can be very complicated to model accurately.
- Good questions were raised for Case Farm B from the modelling process, including the role of maize crops for silage and turnips crops.
- Being ME-based, the programme is very sensitive to pasture quality. Longer term system planning would need to adjust for variations in summer rainfall which affect pasture quality and quantity.
- Physical results were obtained from UDDER using the same pasture growth rates and modelling the solution suggested by the GSL model. Tables 2 and 3 compared the base scenario with two other solutions and showed the changes in profit suggested by the UDDER model.
- Further investigation would be needed to work out the longer term financial impacts of a change, particularly if it required step investments such as sale or purchase of cows and shares, or building infrastructure.
- An understanding of costs, particularly the nature of variable costs, is very important as these can lead to different solutions. For Case Farm B, per cow costs were assumed to be highly variable in relation to cow numbers. For Case Farm C, the per cow costs remained almost static as cow numbers changed, so that if a high per cow cost was used, the system reduced cow numbers, whereas a low per cow cost increased cow numbers.
- The model was capable of differentiating between farms and farming systems as demonstrated by the fact that the model identified quite different issues for Case Farm C compared to those raised for Case Farm B.
- If the GSL model was to be used to predict nitrogen flows and carbon emissions, feed components would need to be separated into energy and protein groups.

The consultant concluded that good useful information was obtained very quickly. The consultant"s knowledge of the farms allowed him to easily verify the model by seeing if the programme was providing sensible results. The next and more difficult step would be to introduce more detail into the modelling e.g. changes in pasture and supplement quality. He speculated that this may make generating an optimum solution more difficult.

This consultant was unlikely to use the GSL model in future as he did not wish to add to the overhead costs of running his consultancy. UDDER suited him because he had purchased a license and the model continued to be useful for the types of decisions required by his consultancy. Additional models would add to consultancy expenses and were unlikely to fit well with the way he interacted with his clients.5.6 Case Comparison

The consultants had quite different approaches to consultancy and the way they used models to work with their clients. The consultancy process summaries (shown below) and the comparative table (Table 4) show some similarities between the two consultants" processes, but also some quite contrasting differences.

Consultant A, whose client was used to participating with him in the use of models:

- Ran the model prior to the visit using data from a "well-known" farm as an initial validation step and to familiarise himself with the model.
- Ran the model using the client"s data from a full year of farming with the client pre-visit.
- Visited the client and his sharemilker, demonstrated the model and results with scenarios,explained the validation process and obtained the client"s tacit concurrence with the model validation.
- Discussed with the client the implications of the GSL model outputs, including those from the MVP data, particularly as they related to the question he was posing.
- Identified a tentative strategy in discussion with the client and sharemilker.
- Arranged a further visit to help clarify the proposed strategy, at the client"s request. This took place once further analysis was completed. After further discussion about the results, it was agreed that the strategy was appropriate. The strategy (of changing calving dates) was put in place immediately to take effect at calving in the subsequent season.

Consultant B, whose clients were used to him running models on their behalf and presenting them with the results:

- Ran the model remotely for each farm using their data from a previous season.
- Satisfied himself that the models represented reality for his clients" farms or that he could account for those areas where it did not e.g. protein content and other attributes of supplementary feeds and concentrates.
- Ran the models to identify optimum resource use for each farm. For client B, this threw up an unanticipated infeasible solution that helped identify that currently there was a lower than expected utilisation of supplements and concentrates.
- Ran a range of scenarios focusing on the management issues he identified for each farm.
- Identified resources that were limiting and alternative strategies to help meet their goals from the scenarios.
- Input the GSL model results from those runs into the UDDER model to test their viability.
- Presented and explained to each client the UDDER model results which were based on the GSL model output. He sought and gained the clients" confidence in the model results.
- Discussed the results with each client, indicating which options he thought were practical to implement on-farm. Client B indicated that he would look for opportunities to discuss the suggested strategies further with the consultant and the farm manager. Client C immediately implemented the strategy (earlier autumn calving) he had earlier identified as being of interest, to have effect for the ensuing season

Table 4: Comparing Differences Between Case Studies			
	Case Farm A	**Case Farm B**	**Case Farm C**
Farm distinguishing features	• High performance with minimal use of concentrates • Recent irrigation	• High performance using moderate levels of concentrates	Winter milk High level of supplement and concentrate use
Farm issues	• Calving date – emphasised since recent changes as calving became compacted and led to feed shortage	• Not clearly identified at first interview • Growing forage crops on farm • Utilisation of concentrates and supplementary feed • Genetic improvement	• Accuracy of diet composition • Continuing with winter milking? • Autumn calving date
Model use by client	• Familiar with most models in use • Able to readily interpret output, including from optimisation model	• Leaves modelling to consultant • Likes to be presented with output • Discusses interpretation with	• Leaves modelling to consultant • Interprets output presented to him for own use
Consultant's approach	• Data-based bench marking • Whole farm approach with simulation models used for physical and financial analysis	• Emphasis on per head performance • Benchmarking using UDDER and personal knowledge • Focus on grazing management, crop agronomy, cow genetics and nutrition using UDDER with an eye to impact on the financials	
GSL model use	• Validated with well- known farm data, then with case farm data • Demonstrated on farm	• Ran model remotely, testing scenarios • Output put through UDDER to present results to clients	
Validation	• Consultant and client accepted the model	Consultant validated the GSL model then further tested scenarios using the UDDER model	
Output	• Client accepted results and requested further analysis • Client acted to change calving date	• Client will give further consideration to recommendations based on output • Unlikely to implement off-paddock feeding system recommendation	• Client accepted some results and changed calving date • Other outputs subject to considerations not able to be modelled

The most obvious difference between the consultants was their approach in conducting the GSL model analyses. Consultant A used the model with the client in attendance, obtained the client"s agreement with the validation and ran the model to obtain results while the client was present. In this way, he could ensure that the client understood the process and theory, and was comfortable that the model was providing a realistic representation of his farming system (that is, validation by the client). Consultant B carried out the analyses prior to the visit, having taken responsibility for model validation himself before doing this. This consultant undertook the analytical computing aspects of model use, then presented his clients with the results and explained how he had interpreted the results and what the most significant effects on their farming systems were. Subsequent discussion about what those results might mean were carried out collaboratively. His clients confirmed that this approach suited them.

The contrasting approaches used by the consultants were consistent with the consultancy style they adopted with their clients. Both consultants were similar in that they regularly use models to assist their clients in decision making, but one presents the final results to his clients while the other works through the model scenarios interactively with his client. Each client is familiar with his consultant"s approach and all expressed satisfaction with the process used with the GSL model and with what they had learned from this. Two of the three clients were prepared to make changes to their system based on what they had learned, and the third was interested in following up the issues raised.

Initial model validation was undertaken to the satisfaction of the consultants and Client A who participated in that part of the process. All three clients were familiar with the use of model output as an aid to decision making. They were also used to the idea of continuing to validate the model.

In this study, model validation was interpreted as "having sufficient confidence in the model to accept the results as the basis for a change in strategy". The consultants" validation processes differed. Consultant A involved his client in model validation which, for them, was an on-going process throughout the visits and analyses. This included specifying sensitivity analyses around situations where the client felt exposed, such as milksolids price and the cost of supplementary feed. While they were happy to accept model output as valid, the consultant did compare GSL model output with that of UDDER and with actual farm production data and noted differences that were within acceptable limits for him. A discrepancy in pasture utilisation between the two models was noted. As the analysis continued, each would comment on results that were consistent or inconsistent with their own experience of their system, demonstrating an awareness of, and informal continuation of, the validation process. Consultant B carried out the validation on behalf of his clients prior to the visit with the client, basing this on his knowledge of their farm systems and their production data. His clients expressed confidence in their consultant"s ability to validate the model on their behalf.

The purpose of the analyses differed between the consultants. Consultant A and his client had identified a clear objective as the basis for the analysis. This was the focus of all of the analyses and was pursued through to finding a strategy that was accepted by both client and consultant. This contrasted with Consultant B and his clients. These analyses were used to identify issues and explore their consequences. The issues were then used as the basis for discussion about strategies that the consultant considered could lead to system improvement. All three clients had gained further insight and understanding of their farming systems.

The consultants were in accord in their approach to learning about the model and their views on model use. Both Consultants were briefed on the use of the model in one-to-one sessions with the developer, and both returned for additional tutorial help once they had begun to work on their own.

They both reported that they had benefitted from discussions with the developer. Both consultants said they found the GSL model easy to use and intuitive, perhaps because they were working directly with the model developer and not having to use a manual. One commented that the means of navigating around the programme could be improved as he found it frustrating to have to move windows and dropdown menus to view the outcomes. While the opportunity did not arise to discuss interactions directly with the model developer, there were indications from discussion with the consultants and the developer that the process was mutually informative.

Consultant A was careful to label profit as an “operating result”, which is similar to a total gross margin as previously explained. Consultant B presented financial output from the UDDER model as gross returns less feed and per cow costs. Both consultants noted that if changes in fixed resources are required, the impact of the fixed resources required may not be captured within the model. Importantly, each consultant recognised that where an increase in the level of a “fixed” resource was needed to increase profit, further analysis would be required.

The GSL model could provide information to inform such investment analyses by indicating the marginal returns to the extra investment, and both consultants used the marginal return information made available by the model (MVP information is described in Chapter 2: Background, Modelling in Farm Management). Consultant A and his client referred to the MVP figures as they considered alternative strategies. In particular, they discussed the model‟s MVP information relating to the use of pasture and other forms of feed at different times of the year. They identified the times of the year when feed was limiting and used that as the basis for investigating alternative scenarios to reduce the use and cost of purchased feed. This gave him the confidence to implement the strategy he had identified. In contrast, Consultant B used the information when carrying out his analysis but did not make direct use of it when communicating the results to his clients. He appeared to make indirect use of MVP information when modelling with the developer prior to the client visits, to identify the value and role of supplementary crops on Client B‟s farm.
The model indicated that it was more profitable to grow pasture than maize or turnips (except at high yields). In the post-visit interview, Client B confirmed this approach, explaining that the issues had been identified by the consultant on his behalf, especially those relating to growing crops. Each client had trade-offs within his farm system. These trade-offs, or opportunity costs, raised further questions that could be appropriately explored using the LP model, but were outside the timeframe of this study.

The way the consultants presented the model output to their clients differed. Consultant A extracted the resulting information manually from the GSL model then constructed a summary of results in a spreadsheet. He noted that if this could be done automatically, it would provide an element of quality control in terms of the user correctly interpreting the information. Consultant B used the UDDER model to generate output to present the results. It was interesting to note that while both consultants recognised that the UDDER model has an optimisation routine, neither indicated that they used this facility.

The model requires access to a web-based server. To do this, Consultant A accessed the model on-farm from his laptop via his cell phone which provided wireless contact to the internet. Consultant B expressed the view that web-based systems are difficult to access in remote areas and where broadband speed is slow. However, the consultancy process he uses is to present results generated off-farm to the client so this may not be of importance to his consultancy

6.0 Discussion

This study investigated two important aspects of LP models. The first research question considered whether LP models could help consultants work with their dairy farmer clients to develop improved pastoral-based systems. The second research question asked how effective and robust the GSL LP model used in this study was as an aid to making dairy farm management decisions. Criteria by which this second question was measured were explained in Chapter 3: Method, Expert Evaluation by a Research Panel. The research questions attempted to distinguish between the information that related to LP in general and to the GSL model in particular. While some attempt at that distinction has been made in this Chapter, the lines are still somewhat blurred.

The real advantages of LP arise from its ability to generate plans for optimum resource use and provide MVPs assuming the other constraints are held constant. The latter information enables users to identify their most (and least) valuable resources and explore ways of using them to advantage. It can confirm users" ideas about what it is that constrains them from doing better. It may also lead to unexpected findings about opportunities and constraints, an important feature of linear programming. The output available from LP models contrasts with that from the simulation models more commonly used by consultants. Like LP models, simulation models can offer useful information about system performance, both biophysical and financial, indicate feasible (and infeasible) systems and help with the redesign of an existing system. It is not necessary to constrain simulation models to be in balance at the beginning and end of the year. On the whole, the way simulation models function, and their outputs, are more readily explained to model users than LP models.

Malcolm (2004) identified two principles of modelling analysis critical to the usefulness of models as being the thought processes surrounding the use of model output, and the need to be confident in model accuracy. The cases used in this study support these views. All three cases demonstrated that the model provoked thinking about setting up, understanding and interpreting model output on the part of consultants and, at times, their clients. While the model outputs can point the way to improved farming systems, the next step in this process will be in planning for implementation, requiring further thought and perhaps analysis (such as financial analysis) to be confident of success in implementation.

Regarding Malcolm"s (2004) second point, both LP and simulation models depend on careful specification of the parameters as well as careful representation of relationships between the components of the model to provide reliable information. The model builder has to take some responsibility for generating these relationships and the user needs to have confidence that the model represents the reality of their farm system. Model validation (as a continual on-going process) has been emphasised in this report as it is critical for both model efficacy and user confidenceThe on-going validation of the model in this study suggests that consultants are aware of the limitations of models and "test" the validity of outputs against their experience before accepting the outputs. Continual validation by consultants and clients also serves to reduce the sense of unease (or riskiness) that clients feel when committing to strategies suggested by the model. The consultants and their clients were confident to devise and implement strategies around the issues identified by the model when they had confidence in the model"s ability to represent the reality of their farm system. This confidence was developed, at least in part, from the relationship between the model developer and the consultant working with data familiar to the consultant.

Consultant B cautioned that not all consultants and farmers have the data to generate pasture growth profiles in the way required for input into the GSL model (see Appendix VI). Consultant A had a similar concern, and selected his client for this study using the quality and quantity of data available from the client"s farm as a selection criterion. Information about the number of dairy farmers who collect pasture growth rate and other data, and the quality of those data, was not available to this study. However, survey research has indicated that only about 20% of farmers use formal feed budgeting, suggesting the majority of farmers may lack the quality and quantity of data required for effective modelling (D. Gray, personal communication, 2013). Further study relating to obtaining and using data for modelling would benefit the general understanding of the use of decision tools and of LP in particular.

Concerns about data quality and availability give rise to the following questions relating to the usefulness of LP models, and the GSL model in particular.

- Given that farmers and managers can be involved in the validation phase of the LP analysis, how critical is it that pasture growth rate and other farm data used in the model are highly accurate? It is possible to envisage situations where indicative data can give rise to a valid model that the consultant and client have confidence in and is fit for purpose, from which systems designs and strategies could be developed for comparative purposes as an aid to decision making.
- In the decade since Malcolm"s (2004) observations, has the quality and quantity of data collected on farms developed to the point where consultants and clients can have confidence in their use in models such as LP models?
- If consultant B"s misgivings about availability of data are valid, does that mean that LP (and/or the GSL model in particular) should be confined to farm systems and research projects where data (especially pasture growth rates) are known to be of high quality?

The two consultants each chose a process that suited their consultancy style, with which they were comfortable and which suited their clients. One consultant used the model interactively with his client and the other consultant operated as an "expert". These processes were quite distinctive, demonstrating that the model can be used successfully in more than one way to meet the needs of consultants and their clients. If consultants want to use the model in different ways it may be appropriate to develop alternative methods of reporting on model output. Consultants could then choose an output mode that suited their approach to model use.
Similarly, the consultants used the model for different purposes: one identified a clear objective as the basis for the analysis, whereas the other consultant used the model to identify issues and

explore their consequences. The decisions were strategic or tactical. Each of the consultants and clients expressed the view that the information was of use to them, demonstrating that useful information can be extracted from an LP model more than one way for these types of decisions. This demonstrates that the model was useful and can be adaptable. Although not noted in the background discussion, the potential for the model to be used to identify unanticipated issues of significance to the farm system was also demonstrated. Further exploration of the particular issue identified (under-utilisation of supplements) was beyond the timeframe of the study but did offer an opportunity to improve system performance.

All users (consultants and experts) found it easy to enter data and to construct a model, but they each would have preferred to have results formatted into a spreadsheet that automatically recorded the data that had been used to construct scenarios together with the results. One consultant identified this as an aspect of the model that detracted from its cost-effectiveness for the client, and that could lead them to favour other models. The other consultant chose to present the GSL output in UDDER model format. Development of such a means of presenting output could also be used to emphasise the use of information from MVPs.

Providing templates for presenting results and the capacity to carry out simple financial analyses would enhance the appeal of the model. This point was made by both the research panel and the consultants. Such templates could be used to emphasize to the user the information provided by MVPs. Similarly, the ability of the model to deal with capital, risk and forage attributes other than energy would enhance its appeal to consultants. Consultants also suggested that a nutritional component could be included in the model, whereby components of purchased feeds as well as their energy content are allowed for. This might add to the processing time, but could offer more flexibility in the analytical phase. Both consultants raised this independently of each other.

Potentially users, who have confidence in a model and are familiar with production economics concepts and marginal analysis, could explore a wide range of issues and possibilities for their farm system. However, MVP information as the basis for scenario and sensitivity analysis may not be immediately obvious to those who are only familiar with other types of models, and may not be able to be readily learnt from manuals. This study demonstrated different ways in which consultants and clients can use the information that LP provides about the MVPs of resources.
However, consultants and their clients who do not have a strong background in production economics and marginal analysis may need to be assisted in recognising, understanding interpreting and taking advantage of this powerful application of LP. The use of MVP outputs would be expected with further experience and familiarity with the concepts. A stronger emphasis on MVP outputs in reporting would assist with this.
Terminology used for the profit measures needs to be clear and consistent. The two consultants and the information provided by GSL all used different terminology in describing the “profit” measure. It appears to be a gross margin and should be described as such in GSL documentation. A manual that clearly describes this profit measure and how it is calculated would be helpful. While the consultants used different terminology to describe this measure, they were aware that the

measure was a gross margin, and if an increase in the level of a “fixed” resource is needed to increase profit, further analysis would be required. If the results are being used for comparing alternatives rather than as an absolute measure of profit, differences in terminology between consultants may be acceptable as long as the consultant is aware of what the measure is and its limitations.

While the expert panel considered that both the content and the presentation of the instructions could be improved, that was not noted by the consultants as a matter of concern. This may have been because they were experienced with models, and had ready access to the developer and the opportunity to learn by interaction rather than by reading manuals. However, not all consultants would have such ready access to the model developer in a commercial situation. Should the model be used more widely in the future, the developer may find it onerous to deal with all his clients on a personal basis and user courses may need to be considered. While one-on-one may be his preferred mode of operating, if he operates in this way in a more commercial environment training this time may need to be factored into the purchase price.

While the two consultants in this study both found the GSL model to have been of use to them,neither was interested in purchasing it. The benefits from using the GSL model were not sufficient for them to use this model to replace or complement their current modelling approaches. Consultant A reasoned that both the time cost of using the GSL model for anything other than straightforward problems, and the time and monetary cost of buying and learning another programme were detractions. Consultant B commented that the GSL model was not useful because of the way he worked with his clients (using UDDER to present output), and the double-handling of data would add further costs for him and his clients.

From a business perspective, consultants‟ time spent learning about the model and interacting with the developer would be covered in their overhead costs so they would need to be sure that the GSL model was going to be an on-going part of their management “tool-kit” in the future to nvest time in this learning. Farmer clients involved in the study were not asked whether they would purchase the GSL model since the model is more suited to consultants than farmers: the transaction cost for individual farmers to learn to use the GSL model would be considerably higherthan that of a consultant who could leverage the skill over a number of clients.

The model needs internet server access in order to run. The panel noted difficulties experienced by institutions due to the firewalls imposed to protect their computing systems. Consultants can also have internet access problems on-farm because of poor rural broadband access, and one consultant did not use models requiring internet access on-farm for this reason. The other consultant overcame this difficulty by using his phone as a hotspot to connect his laptop to the internet and successfully accessed the GSL model. Clearly, access is an issue that needs to be addressed, but the means of improving it was beyond the scope of this study. One possibility could be to develop a cut down standalone version, with the capability to view files and outputs from previous runs, and a facility to export/import data between the two models.

The GSL model is the only LP model available for use by New Zealand dairy consultants and dairy clients. The test as to the "commerciality" of the model is "would people purchase the model?" There are two components to the question: the first relates to the usefulness of the model and the second to its cost-effectiveness as a decision tool which has been the focus of this study. While some models are developed purely for research purposes, the GSL model has been developed for use by people associated with the business of farming. Thus it has commercial application. There was good model support: the developer was prepared to work with clients and made his time and expertise available, both in the technical (LP) area and in the area of dairy farming systems. Once the model is set up, it generates results quickly and effectively. These characteristics of the GSL model, along with those of LP in general, could contribute to its commercial appeal. On the other hand, the GSL Company does not seem to have used contemporary methods of promoting its product within the business world, thus limiting the model"s commercial availability.

Panel members held different opinions as to whether the GSL model could be regarded as "a commercial model", the argument being that a market needs to be established for the model to be regarded as a truly commercial tool, readily available to the dairy industry. The question remains as to whether the GSL model should be considered solely as a research tool or targeted to the consultancy market as well.

The panel commented on commercialisation from two perspectives – that of finding out about the model and that of accessing the model. Finding information on the GSL model seems to arise either from direct contact with the developer or from hearing or reading conference papers, so the primary target seems to be researchers rather than consultants. However, these approaches have not proved particularly effective in promoting the model to consultants who would be the users if the model is to be applied in direct association with New Zealand dairy farmers.

There is room to develop imaginative responses to the various facets of the issue of accessibility. The GSL model may need to be promoted as an alternative analytical tool for consultants to use with farmer clients as well as an aid to research. It could be marketed more directly to consultants by providing more information in a wider range of sources, including the internet. Whatever means is used to promulgate the GSL model, which could be via a website linked to the company"s web address (there is currently no link to the GSL website address) where interested parties could find out more about the model before committing themselves, and making an on-line demonstration model and comprehensive manual available. While a more formal marketing approach may be seen as detracting from the interactive involvement of the developer, it could provide the basis for improved commercialisation of the model. However, given the nature of the current model, it would seem appropriate to first implement the improvements to its marketability noted earlier.

7.0 Conclusions

The aim of this study was to assist DairyNZ to evaluate the role of LP, and in particular the GSL LP model, in assisting consultants and their clients to identify feasible and profitable changes to their farming systems. While the two research questions were formulated to address each aspect independently, the findings for each question were somewhat dependent on the answers to the other.

LP offers dairy consultants and their farmer clients a very useful means of identifying feasible and profitable changes. LP analysis generates information about the optimum use of resources and the opportunity cost of using those resources. Such information provides the opportunity to redesign the farm system and introduce more profitable strategies. However, if users are to make best use of the information from LP they need to be familiar with basic production economics and marginal analysis principles. Industry organisations such as DairyNZ could well consider promoting these principles to industry consultants and farmer levy payers as part of formal and informal education programmes.

The GSL model relies on the farm being studied providing the data to drive the model. This study has raised the question about the availability and quality of such data. Further study in this area could address the questions about the quality and quantity of data required to obtain useful results and about the ability of consultants to model effectively when data are limited.

Model validation was just as important for the GSL model as for other models. Both consultants and one of the clients carried out a comprehensive validation procedure and the GSL model was found to meet their criteria suggesting the model is sound. Both consultants considered the GSL model relatively easy to work with and noted that it generated results quickly. The consultants found it helpful to have worked directly with the GSL model developer in more than one briefing session to gain model experience. The expert panel also found the GSL model to be relatively easy to work with and it measured well against many of the criteria.

The consultants and panel members made a number of suggestions that would help to improve the "commerciality" of the model, such as an improved manual and formal training, better input and output functionality, and better model availability. Potential users expect to be able to easily find information on the model from a range of sources, yet little information is available. If the GSL model is to be more widely used and accepted as another tool in the farm management kitbag, it would be helpful to improve its accessibility, data input and, in particular, data output.

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Errors of omission and commission remain those of the authors.

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10.0 Appendices

Appendix I: Questions asked in Interviews with Consultants and their Clients

Consultant Questions:

Interview 1:

The consultant was asked to describe:

- His regular consulting practices in dealing with clients
- His use of and views about the use of models in general and UDDER and Farmax Dairy in particular
- His previous experience of, and views on linear programming models
  His views on what would be a good outcome for himself and his client

Interview 2:

With Consultant A:

- Both you and your client seemed to accept, and were prepared to devise a strategy based on the output of the model. Is that so and if so why?
- If you were wanting to analyse a developing system how would you go about it?
- The structure of the model required that you adapt your thinking to fortnightly periods including the calving pattern. How much of a problem was that for you?
- Did you achieve a good outcome? (answered in written report).

With Consultant B:

- What level of confidence did you have in the GSL model as an aid to making decisions on the farm?
- Please explain the process by which you used the GSL model to generate an optimum?
- How did you work those results in with UDDER?
- What happened on your second session with the model developer?
  Please explain your use of other models.

Client Questions:

Interview 1:

Each client was asked to

- describe: Their farm system
- How they worked with their consultant
- Any previous experience with models and with LP.
- Any particular issues that they wanted to explore using the GSL model.
- What they considered would be a good outcome for them.

Interview 2:

These questions were based on the previous interview and experiences from the visit(s).

With Client A:

- Both you and your sharemilker seemed to accept, and were prepared to devise a strategy, based on the output of the model. Is that so and if so why?
- The structure of the model required that you adjust the way you thought about calving patterns. How much of problem was that for you?
- In our earlier interview you described what you thought would be a good outcome for you.
- Was that achieved?

With Client B:

- Why do you think the model came up with the results it did about growing turnips and maize?
- What are your thoughts now about utilisation of supplements and concentrates?
- How do you view the use of models for your farm?

With Client C:

- In your previous interview you identified a good outcome. Did that eventuate?
- Will you make changes based on that?
- What do you think now about the issue of variable versus fixed costs?
- Will you continue to produce winter milk?

Appendix II: Consultant A: Report to Client A

GSL Software Trial January 2013 (supplied by Consultant A)

Background

The purpose of this GSL LP trial was twofold.

1. To test the software in a commercial environment, as part of the service request from Massey University.
2. To support client in his search for an optimal farm system in terms of herd size and calving date.

Process

1. The farm was modelled for the current season with a view to validating the tool.
2. We trialled three different calving dates (27 July, 3 Aug & 10 Aug) with three different stocking rates in the tool (450, 488 and 520 cows), with a fixed milksolids payout ($5.50).
3. The outcome from this desktop trial was then presented as a draft to the client and his sharemilker. As a result they requested some further testing to verify sensitivity to payout and supplement price.
4. The software was then used to trial a matrix design to verify the sensitivity as requested. This included one extra stocking rate to verify if there was diminishing returns on 550 cows.
5. This report was drafted to describe the outcomes.
6. A further meeting was conducted with the client to give context around the results and gather feedback.
7. This final report includes the client feedback.

Outcome

The GSL linear program tool has provided a useful insight into the interaction of stocking rate, calving date, payout and price of supplements. Some of these outcomes confirm a natural pattern of thinking and other outcomes provide a challenge for further consideration.

1. Three calving dates were trialled and these indicated that a 3rd of August calving date in the tested environments gave the best financial outcome.
2. At lower herd sizes, 450 – 488 cows the 27th of July calving date could give a similar result.
3. As herd size increased the economic return increased. The client indicated a cap for practical reasons at 520 cows.
4. In the matrix analysis 550 cows was trialled to verify if the marginal gains fell away at higher stocking rates. Where supplements cost 20 cents there were continued marginal gains from increased herd size.
5. As the payout increased the margin increased – this would be expected.
6. At 40 cents for supplement and a $5.00/kg MS payout, the larger herd sizes were clearly less economic.
7. But at higher milksolids payout the cost of higher cost of supplement was more than met as there were marginal gains from increasing the stocking rate.

The client has expressed a need to keep the operating system uncomplicated and repeatable. The capping of the herd size is in part due to this, but requires no further changes to infrastructure. Further points in respect to the client"s request;

1. At 450 and 480 cows the amount of supplement required was minimal. This keeps the practise of feeding cows relatively straight forward.
2. The model described a conflict with 450 cows, the lowest herd size trialled, and trying to keep average pasture cover under 2500 kg DM/Ha. This suggests 450 cows in most seasons would provide some under-stocking based issues or management challenges.
3. At 520 cows and an early calving date there was some instability in the model – suggesting it was very sensitive to early lactation feeding levels. The client reflected that this is consistent with their experience this season (12/13). With a similar herd size and a spring feed deficit, it brought up a management conflict where it was considered uneconomic to fill the deficit.
4. At higher milksolids payout the model would encourage a higher stocking rate and higher inputs, but the benefit of this with payout volatility presents some concerns.

Summary

Given the above, and attached reports, I would suggest the optimal peak cow number is around 480-500 cows, calving at the start of August, requiring modest feed inputs but able to deliver an optimum economic result in a low to medium payout environment.

In a higher payout environment the early August CD remains appropriate but the question could be asked on herd size. The larger herd size would deliver the higher gross margin but brings risk with payout volatility.

There was further discussion around the matrix analysis of payout, herd size, calving date and supplement price/type. This was completed (11/1/13) with a few key comments recorded below.

Response from client

This summary from this software tool, and our collective interpretation increases the confidence to change to a later calving date.

The client has identified that an easy “lever to pull” given an early August calving date, and seasons with higher milk payment, would be to retaining more cows. This could be as simple as culling 20 less cows. This allows the system to be kept simple and repeatable, yet responsive.

Changing herd size is a capital expenditure question. Up scaling to 550 cows would require a new cowshed and possible changes to other aspects of the farm infrastructure. Analysing the cost benefit of this is outside the scope of this report.

However the 550 cow information does give confidence should more cows be carried in any given single season.

The client stressed that a higher input system risks other managerial and environmental challenges.

The tool was used with 20 and 40 cents / kg DM options for the cost of strategic supplements. The 40 cent figure was deemed more realistic.

The farm owners, in consultation with their sharemilker, will take a step wise progression in response to this information. The calving date will be shifted from mid-July to early August.

Preliminary Data: Calving Date and Stocking Rate Trial

2010-11 Season – Calving Date Variation

Calving	Early 15th July	Mid 25th July	Late 5th August
Dry off	Late May	Mid May	Mid May
Cow Numbers	445	445	445
Pasture Harvested	10.1 t DM/Ha	10.1	10.1
Grass Silage	103 t	97 t	89 t
Maize Silage	123 t	107 t	103 t
Palm Kernel	57 t	19 t	17 t
Turnips	87 t	87 t	87 t
Total Milksolids	165488	158997	157215
Milksolids per Ha	1068	1026	1014
Milksolids per Cow	346	333	329
Gross Margin / Ha	3335	3098	3055
Gross Margin / cow	1081	1005	990

2010-11 Season – Stocking Rate Variation

Calving	Mid 25th July	Mid 25th July	Mid 25th July
Dry off		Mid May	
Cow Numbers	408	445	481
Pasture Harvested	10.2	10.1	10.2
Grass Silage	47	97 t	156
Maize Silage	-	107 t	115 t
Palm Kernel	-	19 t	21 t
Turnips	89 t	87 t	87 t
Silage Made	30 Ha	23 Ha	-
Total Milksolids	148160	158997	169964
Milksolids per Ha	956	1026	1097
Milksolids per Cow	338	333	328
Gross Margin / Ha	3230	3098	3204
Gross Margin / cow	1143	1005	959

Calving Date Trial

Calving	Early 15th July	Mid 25th July	Late 5th August
Dry off	Late May	Mid May	Late May
Cow Numbers	450	450	450
Pasture Harvested	12.0	11.9 t DM/Ha	12.1
Grass Silage	40 t	80 t	80 t
Maize Silage	133 t	75 t	72 t
Palm Kernel	57 t	-	-
Turnips	32 t	32 t	32 t
Total Milksolids	195357	186617	185948
Milksolids per Ha	1260	1204	1200
Milksolids per Cow	420	401	400
Gross Margin / Ha	4766	4484	4501
Gross Margin / cow	1589	1495	1500

Stocking Rate Trial

Calving	Mid 25th July	Mid 25th July	Mid 25th July
Dry off	Mid May	Mid May	Mid May
Cow Numbers	413	450	491
Pasture Harvested	11.9	11.9 t DM/Ha	12.0
Grass Silage	-	80 t	133 t
Maize Silage	14 t	75 t	103 t
Palm Kernel	-	-	32 t
Turnips	47 t	32 t	32 t
Silage Made	50 Ha	22 Ha	-
Total Milksolids	172064	186617	202965
Milksolids per Ha	1110	1204	1309
Milksolids per Cow	405	401	402
Gross Margin / Ha	4370	4484	4634
Gross Margin / cow	1594	1495	1422

Appendix III: Consultant A: GSL Model Evaluation

February 2013

The following is my key point assessment of the GSL tool utilised for a single client case study in the late spring 2012.

Ease of use

I found GSL quick to learn, and I had to re-fresh memory on two occasions because of a period of not using it, and this was still manageable.

Navigating around the programme is acceptable but could be improved. The drop down and moving of windows in order to view outcomes was at times frustrating.

Concept of using a linear model while not foreign to me, you still need to remind yourself of the concept and getting your expected outcomes in line with what the tool delivers. At times I was at risk of looking for detail that GSL is not designed to deliver.

Extracting information was done manually and I used a spreadsheet to generate a summary of the trials run. Any future improvements of the software might include a reporting template. Automating this would help users and might ensure an element of quality control in terms of the user correctly interpreting the information.

Process Used for Case Study

My approach was to take an actual year of data for a well-known property then endeavour to generate a similar result using GSL. This was termed the validation step. The time taken to do this is less than the time that would be spent on UDDER or Farmax Dairy.

My client"s primary query surrounded the calving date. The farm was once summer dry and had an early calving date and relatively low stocking rate. With increased irrigation the property now appears to have scope to run more cows, but this has brought pressure on the farm system in early lactation.

I trialled a range of calving dates and stocking rates to identify a possible solution for the client. As suspected this highlighted that a later calving date but a higher stocking rate would be a more profitable system.

After presenting this to the client there was a request to test the system sensitivity to milksolids payout price and supplementary feed cost.

A matrix of scenarios that demonstrated the systems sensitivity was designed and run. This developed the second stage of analysis that was subsequently presented to the client.

I found the tool well suited to this type of client query and the expected outcomes.

Issues

An aspect of GSL that I felt less comfortable with was the manner in which a calving pattern is established.

During the construction/validation phase I had to generate a milk production profile that was as close as possible to the actual year result. To achieve alignment with peak per cow production and the commencement of calving date I felt uncomfortable with not being able to enter a calving pattern.

This issue was not limiting, but did require some adjustment in my thinking and has influenced confidence in the early lactation predictions.

Reserve supplement concept – it was useful to have Barrie instruct me on the use of a supplement that would be utilised by the model and subsequently enabled the model to run through otherwise impassable feed deficits.

However care is needed to identify when this reserve supplement is being utilised, determine what was limiting at this time and then find a workable solution that may ormay not include the “reserve supplement”. A cheap high ME supplement that enables a

trial to run, but not picked up on by the user can lead to incorrect advice.
So this manner of using a reserve supplement to ensure you have more viable outcomes means care is needed that this is correctly accounted for in the final outcome.

Accuracy

Validation outcome – the model was constructed around an actual season and appeared to do this reasonably well. In the 2011/12 season the farm produced 187,253 kg MS plus calf milk.

	GSL	UDDER
Milksolids	199,000 incl calf milk	186,261 + calf milk
Cow Numbers	488	465
Pasture Yield t DM/Ha	14.3 - utilised	12.4 - eaten
Supplements	148	147 t DM
Crop	50 t DM	40 t DM

Compared to UDDER there appears to be a difference in pasture utilised. I cannot confirm if one is more accurate than the other.
I found GSL fast to prepare a model but with less detail entered it would take more trial farms to build confidence that is currently held in UDDER.

Client confidence – the client believed this tool reinforced their ideas on stocking rate and calving date. With the sensitivity analysis it gave confidence that a change in policy would at least deliver the results they are looking for, and they felt this defined a system that would have less risk and greater consistency of outcome year on year.

Reporting

As mentioned above my experience with the tool indicated it rapidly built a useful systems analysis but I had to develop the reporting process.
The client asked questions around sensitivity it would be good if the tool had some means of demonstrating or reporting this.
On screen the GSL is not "pretty". So when/if you show the client something in GSL it is not so easy to present or demonstrate what is happening, unlike UDDER or Farmax Dairy where I am more comfortable with a client looking over my shoulder.
When the client is visually comfortable with what is going on – then they can engage in the model testing process with more ease. As GSL currently works the user/consultant would run the model verify outcomes – shift into a report then come back to engage the client.

Compare

UDDER

- GSL is faster to construct a valid model.
- I would have greater confidence in UDDER, but believe GSL would come up with a similar answer in a shorter time frame.
- UDDER is easier to report from.
- UDDER has an optimisation routine that works in a very similar manner to GSL.
- UDDER has a factorial optimisation which delivers a matrix of solutions that can be achieved with GSL, but GSL requires manual operating – requiring more operator time.
- UDDER can be used as a monitoring tool. So you can design a plan the verify progress against the plan. This is a useful feature for GSL to consider incorporating.
- UDDER does not track prior runs unless specifically saved as a different file. This is a feature of GSL I very much liked.

Farmax Dairy

- GSL faster to establish a model.
- GSL is faster to analyse alternate options and provide information on optimal farm system requirements. This would otherwise be a manual routine in Farmax.
  - GSL does not appear to provide a comprehensive financial analysis or report. This would require further work on alternate software.
  - Farmax does not track prior model runs, and would require manual saving of different files to allow the same style of operation.

Both UDDER and Farmax Dairy are fundamentally energy based systems analysis tools, the same foundation as GSL. What all three tools lack is a "nutrition function".

Cost of time, cost effectiveness for client

I believe GSL would serve a very good niche where the clients want an indicative guide on improvements to a current system.

In some situations where the clients demand for information and detail is straight forward that GSL would be the most cost effective tool to use. For the case study my client would otherwise receive a lower time cost in the account as compared to doing the same task with UDDER or Farmax.

Should the client want more detail - where the information is in GSL but has to be extracted to another reporting software some of the time advantage would be lost in the reporting process. Where the detail is not available – as UDDER and Farmax do provide more information and indices, then the GSL tool might not suffice. Either time would be spent on additional software or UDDER or Farmax might become the preferred tool to use.

Suggestions

- Improvement to the windows and navigation – this would help the user as model runs are completed and may improve demonstration to clients etc. Monitoring facility – if you can enter actual performance against the plan generated by GSL it would take the software into another area where extension people could use the tool.
- Reports – it would be helpful if the tool had some simple reports that might present both tables and graphs for use in the consultant"s reports, or for active demonstration to the client.
- Calving pattern – I would feel more comfortable with being able to engineer the calving pattern to closely simulate real situations.
- Sensitivity template – this would have greatly helped in the case study reported on.
- Given this is a specialist LP tool – perhaps it could be developed to use the matrix approach as used in my case study – but automated as is the case in UDDER. This feature in conjunction with some reporting enhancements would be very powerful to show systems sensitivity and management options in an environment of fluctuating input costs.
- I anticipate the training programme for someone less experienced would be more involved. I suspect a full training requirement might be at least one full day with a follow up day to verify full and correct use. You would need this time initially to work through the concept of LP and ensure Users understand its use and limits.
- If there was a nutrition test as a basic function in the tool that might be useful as NZ dairy is increasingly looking for knowledge on nutritional implications when making diet decisions. This might not fit with the concept for future use of the LP – but for some advisors the feed library could accommodate more nutritional information – and then use this to verify points in the plan where nutrition may not match production expectations.
- Financial model – currently I believe GSL does what it is designed to do and demonstrate marginal changes in economic performance. Being able to have a detailed

financial plan attached would be useful – I think Barry does have this ability to link with a spreadsheet. So users might need to see and use this facility to extract further value.

Case Farm A – example Farmax reports

Profitability (NZD)

FARMAX

Jun 12 - May 13

		$ Total	$ / ha (155)	$ / Cow (475)	$ / kg MS (201940)
Reven	Net Milk Sales - this season	1102197	7111	2320	5.46
	Net Milk Sales - last season	0	0	0	0.00
	Net Milk Sales - dividend	0	0	0	0.00
	Net Livestock Sales	35707	230	75	0.18
	Change in Livestock Value	74321	479	156	0.37
	Total	**1212225**	**7821**	**2552**	**6.00**
Expen	Wages	176225	1137	371	0.87
	Stock Expenses	80750	521	170	0.40
	Supplementary Feed (incl. change in inventory)	90763	586	191	0.45
	Grazing & Run-Off	128440	829	270	0.64
	Other Farm Working Expenses	217297	1402	457	1.08
	Overheads	53940	348	114	0.27
	Depreciation	77580	501	163	0.38
	Total Operating Expenses	**824994**	**5323**	**1737**	**4.09**
Operating Profit		**387230**	**2498**	**815**	**1.92**

FARMAX

Pasture Growth Rate Table for Irrigated

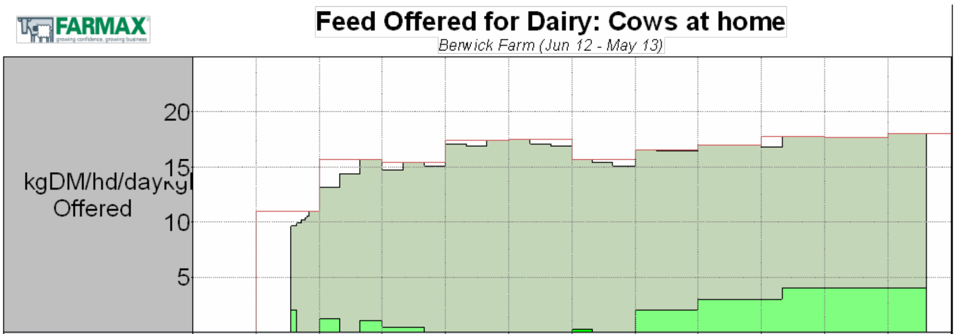
Month	kgDM/ha/d	
	Plan	Adjusted
Jun 12	8.3	2.5
Jul 12	14.3	13.2
Aug 12	25.0	26.6
Sep 12	46.9	49.2
Oct 12	55.0	55.6
Nov 12	60.0	55.2
Dec 12	52.0	55.0
Jan 13	42.0	42.0
Feb 13	36.0	36.0
Mar 13	40.0	40.0
Apr 13	36.0	36.0
May 13	28.0	28.0
Total kgDM/ha	13489	13366

Operating Expenses (NZD)

Jun 12 - May 13

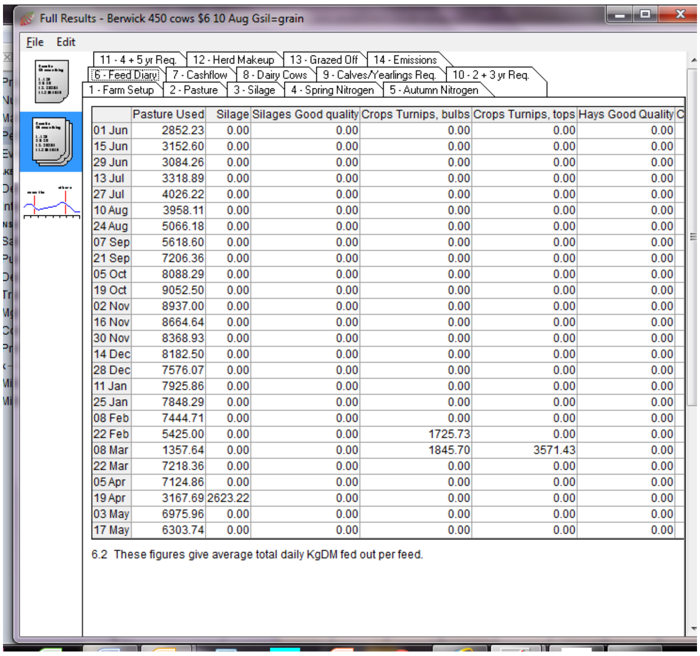
FARMAX

		$ Total	$ / ha (155)	$ / Cow (475)	$ / kg MS (201940)
Labour	Wages	120175	775	253	0.60
	Management Wage	56050	362	118	0.28
	Total Labour	**176225**	**1137**	**371**	**0.87**
Stock	Animal Health	29925	193	63	0.15
	Breeding	18050	116	38	0.09
	Farm Dairy	10450	67	22	0.05
	Electricity	22325	144	47	0.11
	Total Stock	**80750**	**521**	**170**	**0.40**
Feed	Conservation	71037	458	150	0.35
	Forage Crops	17161	111	36	0.08
	Purchased Feeds	0	0	0	0.00
	Calf Feeds	2566	17	5	0.01
	Total Feed	**90763**	**586**	**191**	**0.45**
Grazing	Grazing	128440	829	270	0.64
	Total Grazing & Run-Off	**128440**	**829**	**270**	**0.64**
Other	Fertiliser (Excl. N)	34875	225	73	0.17
	Nitrogen Irrigation	49562	320	104	0.25
	Regrassing	38000	245	80	0.19
	WeedPest	10075	65	21	0.05
	Vehicles	3565	23	8	0.02
	R&M Land & Buildings	32395	209	68	0.16
	Freight	42160	272	89	0.21
	Total Other Farm Working	6665	43	14	0.03
	Administration	**217297**	**1402**	**457**	**1.08**
Overheads	Insurance	19375	125	41	0.10
	ACC	10850	70	23	0.05
	Rates	5270	34	11	0.03
	Total Overheads	18445	119	39	0.09
		53940	**348**	**114**	**0.27**
Depreciation		77580	501	163	0.38
Total Operating Expenses		**824994**	**5323**	**1737**	**4.09**



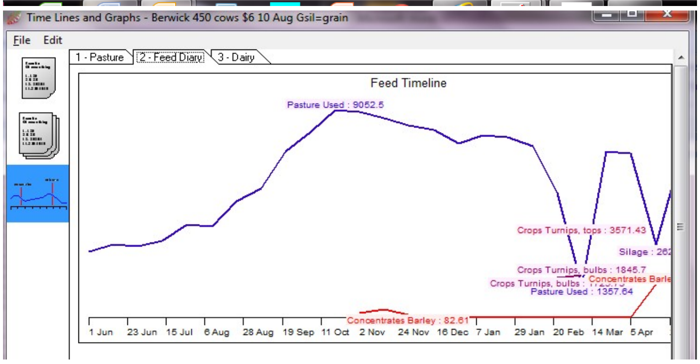
Select a Feed	J	J	A	S	O	N	D	J	F	M	A	M
Pasture		9.4	13.7	14.7	17.1	17.2	15.3	14.5	14.0	13.8	13.7	14.0
Maize Silage F3												
Pasture Silage F2		0.9	0.8	0.3				2.0	3.0	3.7	4.0	4.0
Baleage F2												
Hay big F4												
Runoff Pasture F6							0.1					
Total (Utilised)		8.7	12.2	12.8	14.6	14.6	13.1	13.9	14.2	14.5	14.6	14.9

Compare the above outputs with GSL – using screen shots



	Pasture Used	Silage	Silages Good quality	Crops Turnips, bulbs	Crops Turnips, tops	Hays Good Quality
01 Jun	2852.23	0.00	0.00	0.00	0.00	0.00
15 Jun	3152.60	0.00	0.00	0.00	0.00	0.00
29 Jun	3084.26	0.00	0.00	0.00	0.00	0.00
13 Jul	3318.89	0.00	0.00	0.00	0.00	0.00
27 Jul	4026.22	0.00	0.00	0.00	0.00	0.00
10 Aug	3958.11	0.00	0.00	0.00	0.00	0.00
24 Aug	5066.18	0.00	0.00	0.00	0.00	0.00
07 Sep	5618.60	0.00	0.00	0.00	0.00	0.00
21 Sep	7206.36	0.00	0.00	0.00	0.00	0.00
05 Oct	8088.29	0.00	0.00	0.00	0.00	0.00
19 Oct	9052.50	0.00	0.00	0.00	0.00	0.00
02 Nov	8937.00	0.00	0.00	0.00	0.00	0.00
16 Nov	8664.64	0.00	0.00	0.00	0.00	0.00
30 Nov	8368.93	0.00	0.00	0.00	0.00	0.00
14 Dec	8182.50	0.00	0.00	0.00	0.00	0.00
28 Dec	7576.07	0.00	0.00	0.00	0.00	0.00
11 Jan	7925.86	0.00	0.00	0.00	0.00	0.00
25 Jan	7848.29	0.00	0.00	0.00	0.00	0.00
08 Feb	7444.71	0.00	0.00	0.00	0.00	0.00
22 Feb	5425.00	0.00	0.00	1725.73	0.00	0.00
08 Mar	1357.64	0.00	0.00	1845.70	3571.43	0.00
22 Mar	7218.36	0.00	0.00	0.00	0.00	0.00
05 Apr	7124.86	0.00	0.00	0.00	0.00	0.00
19 Apr	3167.69	2623.22	0.00	0.00	0.00	0.00
03 May	6975.96	0.00	0.00	0.00	0.00	0.00
17 May	6303.74	0.00	0.00	0.00	0.00	0.00

6.2 These figures give average total daily KgDM fed out per feed.



Appendix IV: Consultant B: Notes on the GSL LP Model Presented to Client B

I used last year which was a good grass growing season with atypical summer growth. This resulted in better than average summer production and higher quality over summer. Overall this meant more grass was harvested than usual.

A secondary effect was you had surplus grass silage and maize silage.

Because of your grazing regime based around Danny Donaghy"s system your pasture quality was very high.

Your per cow production was also good, nearly 100,000 kg MS from 252 cows or 400 per cow. My estimate is your cows weigh 420 kg at 4.5 condition score so they are producing at 95% of their body weight. It is possible to go over this ratio but you will need a higher level of concentrates.

The GSL model works by trying to optimise the best return for ME given the natural constraint it needs to use the grass first. So the cost structure and ME content of the feeds is really important. Costs I used for the programme are:

a. $1100 per cow which represents your fixed costs.
b. $300 per tonne DM for bought in feeds, PKE, grass silage and the like.
c. $2400 per ha to grow maize silage on farm grass to grass.
d. $1400 per ha for turnips grass to grass.
e. I also constrained the programme to 2200 kg DM/ha maximum average cover.

In the session I had working through your farm data with the expert we found the farm was sensitive to several key parameters. These were:

a. Grass harvested.
b. Turnip yield
c. N response
d. Wastage of supplement

The model made the most money if you did not grow any maize silage on farm. If felt it could use the grass lost from the maize silage better than the price saving you made with maize silage by growing it on farm. Turnips needed to be yielding better than 7 t DM/ha to be accepted into the system. This made me think about the wisdom of growing turnips on the dry side of the farm. Further analysis may need to be done splitting the farm into two and allowing the model to work out a solution. To deal with the regrassing issue you have two options I can think of. You can go grass to grass doing your preparation in the dry period. You should have a better start to the new grass because it will be in early if you do this. The other solution would be a winter crop that yields better ME than the grass grown over the period you have out. In practice you would grow turnips on the reliable side of the farm and look at other options on the dry side of the farm.

Getting the model to work was only possible if we allowed for lost or wasted feed. The warning bells rang quite loudly, I started with the grass grown from Udder and the feed recorded. We needed to have over 30% wastage of supplement to make the model work. Now this will have impacts the system because the wastage increases the cost of your supplements. I don"t think your pasture harvest was too far wrong but it did beg the question if we could do anything about reducing the waste.

If you want to do more per cow with a low or similar stocking rate then the waste issue becomes really important.

My thoughts are you can look at an in-shed feeding system if you only want to move into more PKE /concentrate feeds or you can look at a more formal feed pad system. There are advantages and disadvantages of both options. The cost of feed and the amount of feed you can get into the system count against the in-shed feeding system. The lack of waste (max 5%) would account for the in-shed feeding system. On a feed pad there is the potential to reduce waste of all feed, give the cows more total feed and you also have a holding / stand off area if you need one. The negative is emotional, and cost and compliance hassles. I have put a rough cost benefit analysis together for you to look at if you went into feed pads.

There were a number of system issues that are unresolved in my mind:

- If you want to push the per cow then you will have to have an active strategy to lift their genetics. I have gone over this with you separately.
- High per cow means specialised feeding to get the most from them. This moves you into more expensive feeds like grain and soy. It also means you need to change some of your management through the dry and transition period.
- Turnips need to be grown very well every year they are in. The model did not want to use any other supplements over summer. But we know for animal performance we must feed a source of fibre. In reality this should not be a problem because most years have less grass over summer.
- I have not resolved adequately the stocking rate pasture harvest issue. Experience tells me that high stocked farms harvest more grass. Low stocked farms harvest less grass. I guess some thought as to what you are trying to achieve with a lower stocking rate would be useful. There is better profit to be made if you lift per cow but not necessarily if you drop stocking rate as well to hold production.
- Growing the maize silage on farm helps capture the high grass peak growth effectively. So I am not fully committed to the no maize silage option.

Appendix V: Consultant B: Notes on the GSL LP Model Presented to Client C

I was interested to see how the linear programme coped with a farm operating at your level. For this reason I took this year which was a new high in term of physical performance.

Working through the options helped me to understand how the programme made its decisions. It focuses on energy and the cost of getting the energy. It works with a given grass curve and animal performance. Allocating the costs play a critical role in its decision making process.

Because of your grazing regime based around Danny Donaghy"s system your pasture quality was very high.

Your per cow production is superb, 117% of bodyweight. Per hectare performance is right up the top end because you have combined high stocking rate and high per cow. The high production figure per cow figure is reflected in high feed conversion efficiencies, 10.8 – 10.9 kg DM/kg MS. (I have not included any dry cow feed or rearing young stock in the feed conversion efficiency. If I included the dry cows then the feed conversion would change by approximately 1kg DM/kg MS to 11.8 – 11.9 kg DM/kg MS. High feed conversion efficiency drives income per kg MS. So you are earning about 56 cents per kg DM eaten – about 10 cents per kg of dry matter consumed more than most other farmers.

The GSL model works by trying to optimise the best return for ME given the natural constraint it needs to use the grass first. So the cost structure and ME content of the feeds is really important. Costs I used for the programme are:

- $300 per cow which represents the variable per cow costs. As we discussed your system is relatively inelastic. There will be some step functions with big changes in cow numbers but very little change with small changes in numbers.
- $300 per tonne DM for bought in feeds, grass silage and the like.
- A range of $550 - $670 per tonne for concentrates.
- $2400 per ha to grow maize silage on farm grass to grass.
- I also constrained the programme to 2200kg DM/ha maximum average cover.

In the session I had working through your farm data with the expert we found the farm was sensitive to several key parameters. These were:

- Winter Milk payout.
- The cost of concentrates.
- Variable cost of running cows.

If I used a high variable cost for cows then the programme wanted to reduce cows as much as possible to reduce the cost of supplements. If I used a low variable cost then the model wanted to increase cows to make the most money it could from the feed it had.

The cost of concentrates impacts on the earnings at your feed conversion. Interestingly enough the machine still wanted to use concentrates even though at high concentrate costs you were not making money on straight feed conversion. The programme did want to drop cow numbers in this state.

I am not sure the programme can provide step changes in system so there is some interpretation of results needed to develop further strategies.

In terms of winter milk, I think there are two ways to arrive at a winter milk option. One way is driven there by poor mating performance and lots of carry-over cows. The other way is to embrace it as a way of getting a premium because you are milking cows for 300 day lactations so calving some in the autumn allows you to capture the premium. You are in the second category with all cows doing 300 days and only a few carry-over cows.

I allowed the machine to select the autumn calving date. The result indicated that it liked a slightly earlier date, perhaps one week earlier. This matched your grass curve and the thinking that it is better to calve slightly earlier than the grass growth either in spring or autumn.

Grass harvest figures shown on the spread sheet include nitrogen grown grass. This lowers the raw grass grown figure to around 10 t DM. This at first glance is disappointing but the drought should be factored in.

My take home points for the exercise

- are: Cost control is critical.
- Variable cow costs and cost of feed especially concentrates are key.
- Winter milk adds value but not a huge amount.
- Calving date could be moved slightly earlier in the autumn.

My own knowledge suggests more cows would not be a wise move but it is unlikely that you will gain much from dropping cow numbers by much.

Appendix VI: Consultant B: GSL Model Evaluation

I found the programme easy to use and intuitive. I am not a fan of web based systems because it can be difficult to access in remote areas. Putting in the data was simple provided there was an understanding about energy balances and animal characteristics. I was lucky I had very good grass growth profiles for the farm. This gave a foundation from which to build. It may have been more difficult if the grass profiles were uncertain.

A significant value in the approach was as an audit. It re-questioned some of the standard responses and strategies used on the farm. Like any evaluation system any implementation will need to have supporting strategies. For example, on Case Farm B improved genetics and improved supplement utilisation seemed to have the biggest gains. To achieve this there would need to be formal strategies in place. For instance to improve utilisation of supplements different feeding systems need to be looked at. If genetics is going to be pushed then there is the interface of actually lifting the genetics and then feeding the cows properly (both in total ME and balance) to allow the cows to express their genetics.

Good questions were raised particularly for case farm B. These questions developed from the modelling process. Things we need to explore are the role of crops. Maize silage and Turnips are grown on farm presently. The maize yield is always in excess of 20 t DM/ha which makes it a cheap crop to grow. The turnips on the other hand are not so clear cut. The poor turnip crop relates to which half of the farm we grow them. This then raised the question about why the farm was undeveloped.

The weaknesses of any modelling system are based around systems and nutritional issues. In real life, if turnips were grown over summer then we would always use a source of effective fibre. GSL did not see the need for silage based on ME over summer.

Being ME based the programme is very sensitive to pasture quality. In the year we chose the grass grew very well over summer, there was enough rain to provide both quality and quantity. Longer term system planning would need to adjust for this.

I have attached a summary of physical results obtained from Udder. I used the same pasture growth rates and implemented the solution suggested by GSL. Each table compares the base with two other solutions and the change in profit suggested by Udder. The movements correlated but with any of these programmes further investigation would be needed to work out what the financial impacts of a change were. This is particularly important if there were step investments to be made. Sale or purchase of cows and shares or building infra-structure can change the financial picture quite considerably.

An understanding of costs is really important. Depending on the variability of each component the model will drive to different solutions. For Case farm B I assumed the costs were strongly variable and related to cow numbers. For Case Farm C the costs are almost static.

Looking at Case Farm C the questions the model raised were different. To me this was a positive point because it meant the model was capable of differentiating between farms and farming systems.

The importance of getting the financial variability right is crucial. With the Case Farm C system if a high per cow cost was used then the system wanted to drop cows. A low per cow cost meant the system wanted even more cows on the farm.

I noted the GSL model had the ability to model nitrogen flows. To do this the feeds would need to be separated out into energy and protein groups. I only had three feeds for Case Farm C, grass, silage and concentrates. More constraints would be needed to ensure minimum nitrogen levels were achieved and consideration given to the use of by-pass protein which forces soy into the system.

The model seems to drive feed profit through optimising the cost of energy and maximising feed conversion. At high levels of per cow performance the system can be very complicated to model accurately.

One issue to look at is that for all my clients I have a heavy reliance on information and model their farms. I update the model (recalibrate it) each visit to provide an accurate predictor looking forward. What I have observed is very few farmers are really interested in the nuts and bolts once they have seen the first session or two.

A final thought, I got good useful information very quickly. Applying my knowledge of the farms allowed me to see if the programme was providing sensible results. The next and harder step would be to calibrate the programme down to more detail. How this would impact its ability to optimise the programme I am not sure.